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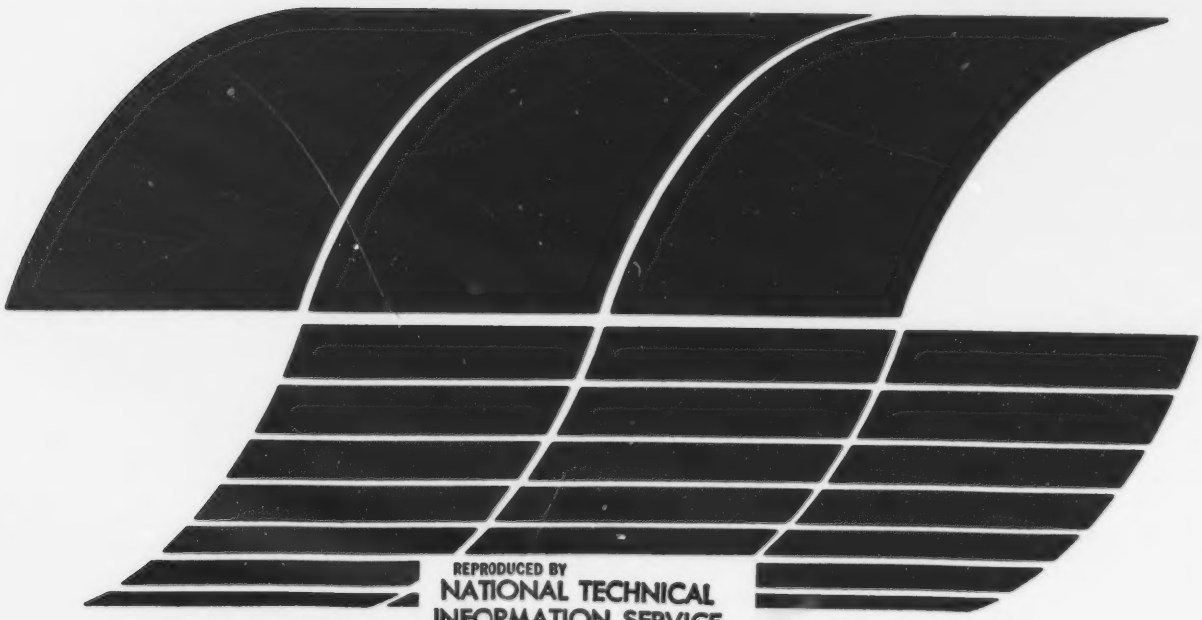
Aerosol Source Characterization Study in Miami, Florida

Trace Element Analysis

Interagency Energy/Environment R&D Program Report



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Trace Element Analysis

by

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SECTION 1

INTRODUCTION

The City of Miami offers a unique opportunity to study an aerosol primarily derived from a marine atmospheric background, modified by naturally derived aerosol components such as soil dust, nonindustrial urban activity, light industry, stationary power generation plants, and automotive emissions (Hardy et al. 1976). Activities in the Miami area are primarily service oriented, the area being a resort and retirement community. Approximately 25 percent of the work force is employed in wholesale and retail trade. The next largest categories of employment are professional and related services; manufacturing; transportation, communications; and public utilities. These categories comprise nearly 65 percent of the total employment in the Miami area. The largest manufacturing industry is apparel manufacturing, then machinery, metal products and equipment manufacturing, in that order (Epstein and Lynn, 1976). No heavy industrial activity is carried on in the Miami area.

In order to aid in the characterization of an atmospheric aerosol, knowledge of the trace element concentrations as a function of particle size, time, and meteorological conditions, in addition to the normally measured parameters, such as total aerosol mass, is necessary. A study was undertaken in June 1975 with the cooperation of the Dade County Pollution Control Department and the U.S. Environmental Protection Agency for aerosol characterization in Miami, Florida.

In this study, Dade County sampling sites 10, 11, and 14 were chosen. These were located at 6400 NW 27 Avenue, Miami; 251 E. 47 Street, Hialeah; and 7700 SW 87 Avenue, Miami; respectively. Sites 10 and 11 were close to light

industrial activity, and site 14 (background site) was primarily a residential area in southwest Dade County. All sites were exposed to high automotive traffic density. The sampling sites are indicated on Figure 1.

Sampling devices at each station included a five-stage Battelle design cascade impactor (Mitchell and Pilcher 1959), an eight-stage Andersen cascade impactor (Andersen 1966), a streaker sampler giving 2-h time resolution (Nelson et al. 1975), and a hi-vol sampler to measure total aerosol mass. In addition, sampling site 10 was equipped with an experimental wind-direction-sensitive sampling system (DeJong et al. 1978), operating four Battelle impactors to sample only when the wind was blowing from a selected 90° quadrant and above a predetermined minimum velocity. The four quandrants were centered around the northeast, southeast, southwest, and northwest directions. The Battelle cascade impactors classified particulates into six size ranges of $d < 0.25$ μm, $0.25 < d < 0.5$ μm, $0.5 < d < 1.0$ μm, $1 < d < 2$ μm, $2 < d < 4$ μm, and $4 < d$ μm, equivalent aerodynamic diameter (Mitchell and Pilcher 1959). The inlet cutoff diameter for both the streaker and the Battelle impactor is ~ 15 μm, compared to ~ 100 μm for the hi-vol sampler diameter. The streaker is a continuous sampling device utilizing 0.4 μm pore size Nuclepore filters that can give 2-h time resolution from a 0.12 m^3 sample (Nelson et al. 1975). The streaker and cascade impactor samples were analyzed by proton induced x-ray emission (Johansson et al. 1972) at Florida State University. The hi-vol samples were weighed by the Dade County Department of Pollution Control to determine the total aerosol mass and analyzed by the U.S. Environmental Protection Agency (Research Triangle Park, North Carolina) for total hydrogen, carbon, and nitrogen content. Remaining portions of the hi-vol samples and selected Andersen samples were microscopically analyzed by the IIT Research Institute (Draftz 1979).

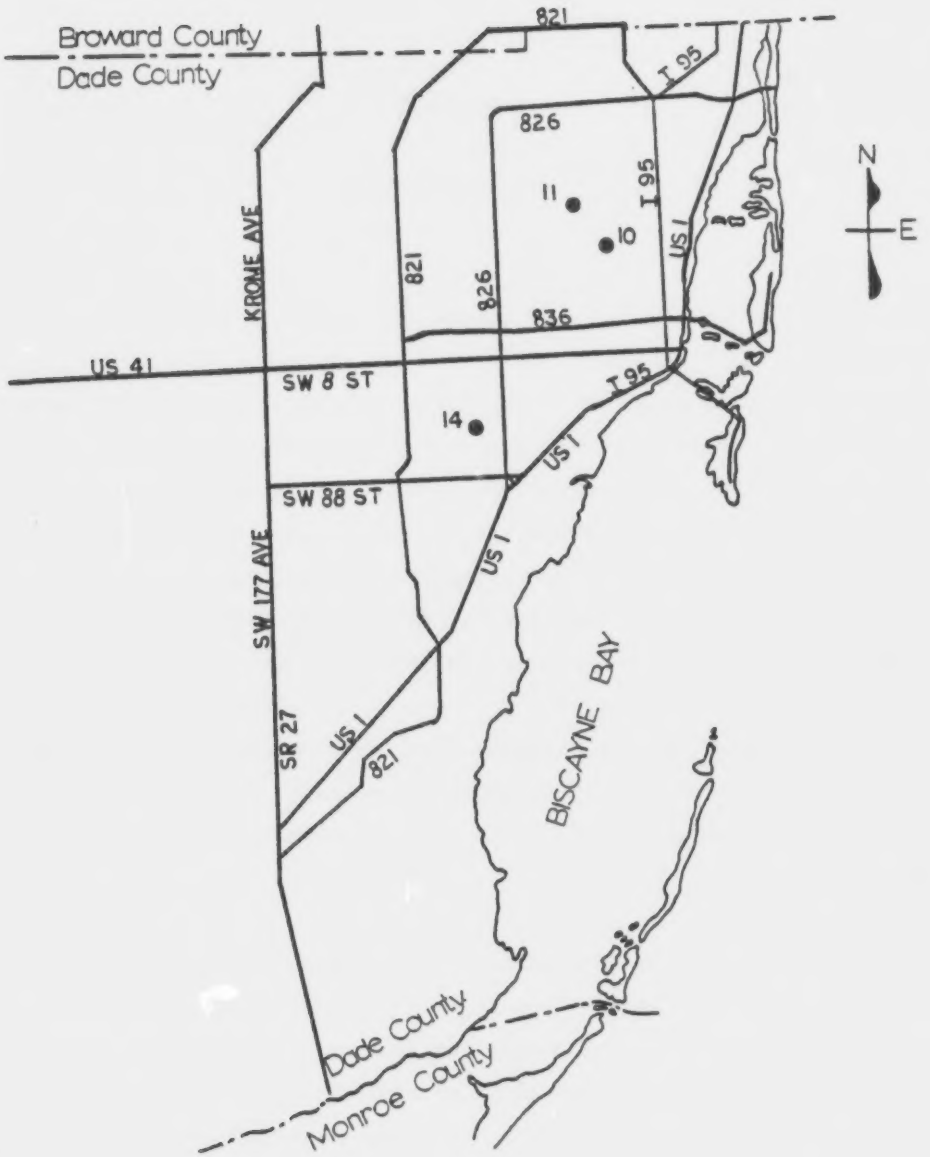


Figure 1. Map of Dade County, Florida, indicating sampling sites 10, 11, and 14

SECTION 2

RECOMMENDATIONS

This study characterized the aerosol in Miami in general terms. Several problems remain to be solved before a better characterization of the aerosol can be made. To enable better calculation of the source coefficients, the elemental composition of natural aerosol sources must be studied. For example, during specific meteorological conditions, a considerable fraction of the particulate matter in Miami may be transported from the Sahara Desert (Savoie and Prospero 1976). The elemental composition of soil dust and limestone dust should be determined for the Miami area. The method of finding the directional distribution of particulate matter should be perfected by a longer-term study in an area such as Miami. The contribution of the Everglades to the aerosol burden in Miami must be determined; as this study indicates, the Everglades may be a significant source of sulfur particulates. The marine environment contribution to the aerosol burden should be determined with more precision.

The national emission inventory must be updated to take into account sources other than fuel combustion. A small manufacturing operation involving arc welding may contribute a significant portion of the particulate burden of iron, for example. Turbojet aircraft emissions should be studied, as they are a large source of particulate matter at sites under their flight path.

It is of interest to compare the particulate levels observed in this June 1975 study to those observed a year earlier (Hardy et al. 1976). The sampling was not at the same locations, but the data indicate the particulate levels have not changed significantly.

SECTION 3

EXPERIMENTAL CONDITIONS AND PROCEDURES

Samples were collected in Dade County between 6/2/75 and 6/12/75. Three sampling locations were selected; sampling site number 10 was centered in a light industrial area, sampling site number 11 in a densely populated residential area, and sampling site number 14, the background site, was located in a lightly populated residential area in southwest Dade County. The streaker samplers were operated continuously for the sampling period. The hi-vol samplers and the Battelle cascade impactors were changed on a 24-h basis. The wind direction Battelle samplers were changed when a sample large enough for analysis was collected. Weather observations were made at Miami International Airport by the National Oceanographic and Atmospheric Administration. The surface wind speed and direction were averaged over 3-h intervals. Radiosonde observations were made at 7:00 am and 7:00 pm and were used to obtain information about the mixing height and temperature inversions. The mixing height, as determined from the radiosonde data, was generally about 1,000 ft. Trace precipitation occurred on 4 days during the sampling period, and thunderstorm activity on 3 of these. Temperature inversions were evident in the morning observations, and on 6/5 the inversion persisted all day. A weak low pressure system passed over the South Florida area on 6/6 and 6/7. Table 1 summarizes the meteorological data during the sampling period.

TABLE 1. METEOROLOGICAL CONDITIONS, 6/3/75 to 6/13/75

Date	Resultant wind speed (km/hr)	Resultant wind direction (degrees)	Inversions[a] 7:00 am
6/3	3	70	mild
6/4	3	340	weak
6/5	3	230	mild
6/6	2	180	mild
6/7	15	240	mild
6/8	10	220	strong
6/9	4	180	strong
6/10	10	130	mild
6/11	13	100	mild
6/12	2	110	mild
6/13	4	170	mild

[a]The inversions are classified weak, mild or strong, depending on the divergence of the radiosonde data from the normal adiabatic lapse rate.

SECTION 4

DATA ANALYSIS

The hi-vol sampler filters and aerosol samples collected with Andersen eight-stage cascade impactors were microscopically analyzed. The results are summarized in a separate report (Draftz 1979).

SIZE DISTRIBUTION DATA

From the cascade impactor samples collected at each site, nine sets of size distribution data were selected for analysis. Five sets of size distribution data from Dade County site 10 were selected, two from site 11, and two from site 14. The size distribution data are presented in Figures 2 through 13. To simplify data analysis, the size distributions from site 10 for 6/2, 6/3, and 6/4 were averaged, and the size distributions for 6/11 and 6/12 were averaged.

The mass weighted mean diameter, $\bar{d}$, useful in characterizing elemental size distributions, is defined as:

$$\bar{d} = \frac{\sum_{i=1}^{6} m_i d_i}{\sum_{i=1}^{6} m_i} \qquad \text{(Eq. 1)}$$

where i = summation index, specifying the stage of the cascade impactor

m_i = mass collected on stage i

d_i = average equivalent aerodynamic diameter of particulates collected on stage i

The assignment of the average diameter is somewhat arbitrary, as stages 1 and 6 are open-ended. The diameters used in the calculation were 0.19, 0.37, 0.75, 1.5, 3.0, and 6.0 μm for stages 6 through 1, respectively. The nine sets of distribution data shown in Table 2 are useful to compare the samples collected with similar devices (Battelle cascade impactors) at the different sites. The error in these figures is ~ 20 percent.

WIND-DIRECTION-SENSITIVE DISTRIBUTION DATA

From the site 10 wind-direction-sensitive system of four cascade impactors, four sets of data were analyzed. Elemental size distribution as a function of wind direction are presented in Figures 14 to 16. Each of the four impactors was operated in its selected sector when the wind was blowing from that sector, until (after ~ 24 h) a sample sufficient for analysis was collected. These samples, therefore, represent an average over time periods that are different for each wind direction. The mass mean diameters were calculated using Equation 1 and are presented in Table 3. Lines connecting the data points in Figures 14 to 16 are to aid the eye in following the data trend.

DISTRIBUTION AS A FUNCTION OF TIME

The time distribution of particulates was measured with streaker samplers at all sampling sites throughout the sampling period (Nelson et al. 1975). The data are presented in Figures 17 to 22. A traffic count taken adjacent to site 10 is shown on Figure 19. The observed correlation between lead and bromine (Figure 19) is as expected. Levels of some soil-derived elements appear correlated with wind velocity; for example, K, Ca, Ti, Cr, Mn, Fe, and Ni levels increase on 6/7, 6/8, 6/10, and 6/11 (Figures 17 and 18). A surprising result is the lack of correlation between the traffic count taken adjacent to site 10 and the levels of lead and bromine at that site (Figure 19).

TABLE 2. MASS WEIGHTED MEAN DIAMETER (μm), SITES 10, 11, AND 12

Element	Site 10 (June 2,3,4)	Site 10 (June 11,12)	Site 11 (June 5)	Site 11 (June 12)	Site 14 (June 5)	Site 14 (June 12)
P	1.88	2.79	2.25	3.01	2.86	3.44
S	1.09	2.06	1.35	0.85	1.04	1.66
Cl	4.15	4.88	4.69	4.90	3.88	5.17
K	2.60	3.50	3.08	2.71	2.91	3.29
Ca	4.00	4.86	4.07	4.89	4.30	5.40
Ti	1.48	3.05	2.50	2.92	2.08	3.03
V	0.62	0.98	0.33	0.52	0.53	0.48
Cr	1.30	4.44	0.41	-	-	1.28
Mn	1.94	3.11	1.00	3.08	3.67	3.15
Fe	2.77	3.01	3.35	3.00	3.49	3.53
Ni	2.24	2.02	4.12	3.99	2.78	2.18
Cu	1.84	1.33	2.02	2.19	2.51	1.80
Zn	2.03	4.01	3.02	2.09	2.92	2.49
Br	1.53	1.17	2.05	2.00	2.28	3.22
Pb	1.29	1.12	1.69	1.07	2.18	2.23

TABLE 3. MASS WEIGHTED MEAN DIAMETER (μm) FROM SELECTED SECTOR IMPACTORS, SITE 10

Element	NE	SE	SW	NW
P	2.23	1.25	2.29	0.4
S	1.34	1.01	1.45	1.31
Cl	4.80	4.44	4.29	1.78
K	3.11	2.76	3.10	1.22
Ca	4.95	3.90	4.67	1.55
Ti	2.27	1.62	2.48	2.22
Fe	3.35	2.38	2.98	2.94
Cu	3.31	2.09	3.01	3.12
Zn	3.18	2.42	2.97	3.07
Br	1.96	1.53	1.93	0.96
Pb	1.30	0.93	2.07	0.73

AEROSOL SOURCE COEFFICIENTS

A useful way of analyzing air particulate data is the computation of the aerosol source coefficients (Miller et al. 1972). The concentration of air particulate matter at a sampling site due to several sources can be written:

$$C_i = \sum_j \alpha_{ij} \gamma_{ij} m_j \qquad \text{(Eq. 2)}$$

where j = source of the particulate matter

C_i = concentration (ng/m^3) of an element i at the collection site

α_{ij} = fractional composition of element i emitted by source j

m_j = mass of particulate matter attributable to source j

γ_{ij} = coefficient of fractionization, describing the loss of element i between the source and the sampling station

The m_j's may be determined from the experimentally observed concentrations by a linear least squares criterion. The quantity minimized is:

$$Q = \sum_i \frac{(x_i - \sum_j \alpha_{ij} \gamma_{ij} m_j)^2}{\sigma_i} \qquad \text{(Eq. 3)}$$

which takes into account the error (σ_i) in the observed concentration (x_i). In general, the γ_{ij} coefficients are not known but can be assumed to be close to 1. The α_{ij} coefficients describe the composition of an aerosol emitted by a source j; these are known for anthropogenic sources but less well known for natural sources. In the calculations presented here, γ_{ij} is taken to be 1. The method is satisfactory for total particulate matter, however less satisfactory for particulate matter classified by size, because the fractional composition for particulate matter as a function of particle size is not well known.

In the calculation it was assumed that the aerosol evolved primarily from six major sources: sea salt, fuel oil fly ash, cement dust, automotive emissions, limestone, and soil. In the composition of fuel oil fly ash, a 10 percent conversion of SO_2 to particulate matter was assumed. Table 4 shows the assumed source fractional composition for the major components of Miami aerosol.

TABLE 4. FRACTIONAL ELEMENTAL COMPOSITION OF MAJOR SOURCES OF MIAMI AEROSOL

Element	Limestone[a]	Cement[b]	Automobile[c]	Fuel oil fly ash[d]	Soil[e]	Sea salt[f]
P	0.31×10^{-3}	0	0	0	0.26×10^{-3}	0.34×10^{-6}
S	0.30×10^{-3}	0.10×10^{-1}	0.10×10^{0}	0.39×10^{0}	0.19×10^{-3}	0.26×10^{-1}
Cl	0	0	0.69×10^{-1}	0	0.48×10^{-3}	0.55×10^{0}
K	0.27×10^{-2}	0.80×10^{-3}	0	0.39×10^{-2}	0.24×10^{-3}	0.11×10^{-1}
Ca	0.30×10^{0}	0.46×10^{0}	0.48×10^{-1}	0.18×10^{-2}	0.13×10^{-2}	0.16×10^{-1}
Ti	0.35×10^{-3}	0.18×10^{-2}	0	0.13×10^{-3}	0.3×10^{-2}	0
V	0	0	0	0.11×10^{-1}	0	0
Cr	0	0	0	0.53×10^{-3}	0	0
Mn	0	0.30×10^{-3}	0	0.13×10^{-3}	0	0.30×10^{-6}
Fe	0.38×10^{-2}	0.21×10^{-1}	0.82×10^{-1}	0.11×10^{-1}	0.23×10^{-2}	0.1×10^{-5}
Ni	0	0	0	0.25×10^{-1}	0	0
Cu	0	0	0	0.66×10^{-3}	0	0.26×10^{-5}
Zn	0	0	0.12×10^{-1}	0.12×10^{-3}	0	0.40×10^{-6}
Br	0	0	0.15×10^{0}	0.13×10^{-3}	0	0.19×10^{-2}
Pb	0	0	0.41×10^{0}	0.79×10^{-3}	0	0

[a] Pettijohn 1948
[b] American Society for Testing and Materials
[c] Cahill and Feeney 1973
[d] Winchester and Desaedeleer 1975
[e] Parsons 1897
[f] Sverdrup 1942

TABLE 5. RESULTS OF SOURCE COEFFICIENT CALCULATION ($\mu g/m^3$)

Element	Site 10		Site 11		Site 14	
	Observed	Calculated	Observed	Calculated	Observed	Calculated
P	325 ± 160	5[a]	270 ± 135	7[a]	192 ± 100	8.6
S	620 ± 250	628	745 ± 350	746	1110 ± 200	1109
Cl	650 ± 260	655	251 ± 100	253	240 ± 100	242
K	209 ± 60	25[a]	195 ± 78	40[a]	167 ± 67	44
Ca	4340 ± 800	4341	3440 ± 1300	3441	3830 ± 1000	3830
Ti	29 ± 6	70	18 ± 7	46[a]	30 ± 10	75[a]
V	12 ± 3	9	19 ± 10	13	9 ± 4	26[a]
Cr	24 ± 8	0.5[a]	3 ± 1	0.7[a]	2 ± 1	1.3
Mn	12 ± 5	2.8[a]	8 ± 4	0.2[a]	6 ± 3	1[a]
Fe	485 ± 100	392	285 ± 100	272	280 ± 80	246
Ni	22 ± 11	20	8 ± 4	32[a]	7 ± 4	62[a]
Cu	10 ± 5	0.15[a]	104 ± 50	0.9[a]	3 ± 2	1.6
Zn	33 ± 11	22	45 ± 23	27	20 ± 8	13
Br	132 ± 40	274	255 ± 100	337	88 ± 30	157[a]
Pb	780 ± 230	745	950 ± 200	921	440 ± 80	429

[a]These calculated values are not within one standard deviation of the observed values.

Table 5 presents the calculated elemental abundances, while Table 6 presents the calculated aerosol source composition. The aerosol source coefficients were calculated from elemental abundances obtained by averaging the observed mass on each stage and summing these averages over the six stages. When a stage was missing, a size distribution was assumed, including an assumed value for the missing stage. In most cases, the agreement between the calculated and observed elemental abundances was good with the exception of phosphorus, where the observed value was always much higher. The total mass calculated for sites 10 and 11 is lower than the total mass observed in the hi-vol sampler measurements; nevertheless, since the calculation reproduces the elemental abundances, it is a good representation of the aerosol composition as measured by the cascade impactors. The composition of cement dust and limestone are notably similar, and their sum is ~ 30 percent of the total mass at all sites. The soil component is ~ 50 percent of the total mass. The automobile component varies from 3 to 8 percent, the background site (site 14) having 3 percent. The fuel oil fly ash component varies from 3 to 7 percent, with the larger source coefficients at sites closer to fossil fuel power plants. Sea spray is a minor component of the aerosol observed at the three sites, the greatest component being 3 percent. Background site 14 calculated total mass, 37 µg, (Table 6) agrees well with the observed total mass at the background site (Table 7), where the average hi-vol measurement was 32 ± 12 µg.

TABLE 6. CALCULATED SOURCE COEFFICIENT FOR MIAMI AEROSOL (% OF TOTAL MASS)

Component	Site 10	Site 11	Site 14
Sea salt	3	0.6	0.7
Cement dust	30	-	6
Auto	6	8	3
Fuel oil fly ash	3	5	7
Soil	59	48	59
Limestone	-	38	23
Mass	30 µg	28 µg	37 µg

TABLE 7. RESULTS OF HI-VOL MEASUREMENTS ($\mu g/m^3$)

Date	Site 10				Site 11				Site 14			
	Mass	C	H	N	Mass	C	H	N	Mass	C	H	N
6/2	69.1	7.6	0.55	0.29	51.6	6.8	0.51	0.33	--	--	--	--
6/3	67.4	8.2	0.67	0.50	50.1	7.6	0.64	0.61	16	3.3	0.25	0.20
6/4	52.9	--	--	--	40.5	5.2	0.54	0.58	31.1	3.9	0.4	0.43
6/5	81.1	9.7	0.83	0.98	55.8	6.9	0.63	0.85	31.9	3.7	0.4	0.45
6/6	94.9	11.5	1	1.73	73.1	8.7	0.84	0.97	30.4	4.4	0.5	0.46
6/7	44.9	4.6	0.38	0.36	--	--	--	--	19	2.2	0.2	0.2
6/8	--	--	--	--	27.1	3.5	0.29	0.27	19.2	2.19	0.2	0.18
6/9	--	--	--	--	--	--	--	--	29.2	3.4	0.26	0.26
6/10	83.9	5.9	0.55	0.37	72.2	5.4	0.53	0.50	51.2	3.2	0.4	0.26
6/11	84.0	5.9	0.63	0.38	66.4	4.6	0.54	0.39	44.3	2.26	0.31	0.23
6/12	83.1	7.2	0.68	0.79	67.3	--	--	--	48.1	3.65	0.4	0.5
Mean	74 ± 16	7 ± 2	0.6 ± 0.2	0.7 ± 0.5	56 ± 15	6 ± 2	0.6 ± 0.2	0.6 ± 0.3	32 ± 12	3.2 ± 0.8	0.3 ± 0.1	0.3 ± 0.1

Agreement at the other sites is not good. At site 10, calculation accounts for 40 percent of the observed mass, and at site 11, 50 percent of the observed mass. The major cause for this nonagreement is that calculation could not account for the many small sources in these two industrial areas. In addition, the cascade impactor's first stage is an open size interval $d > 4$ μm; however, the efficiency probably drops for $d > 8$ μm. The efficiency of the hi-vol samplers used is not well known, but probably is better than the efficiency of the cascade impactors for $d > 8$ μm.

DIRECTIONAL DISTRIBUTION OF PARTICULATE MATTER

The directional distribution of the elemental concentration of particulate matter may be determined by combining the information obtained from the streaker samplers with meteorological information. The streaker samples were sorted into groups with a 10° change in wind direction, and the observed concentration in these groups was averaged. The results are plotted in Figures 23 to 33. The plot radii are shown in Table 8. The most striking example of the usefulness of the method is shown by the distribution of lead and bromine at background site 14. The peak in the lead and bromine directional distribution is to the southwest, pointing toward a large county-operated filling station. This local source also accounts for the unusual size distribution of lead and bromine at this sampling site. Analysis of the directional distribution of pollutants is simplified at site 14, where fewer local sources exist. Some of the distributions at site 14 can be accounted for by the sources listed in Table 9. Sites 10 and 11 present a more complex analysis problem; however, the distribution of some elements may be understood without knowledge of individual sources. At site 10, the sulfur peak to the southeast points to a small fossil fuel power plant, the chlorine distribution is primarily to the east, potassium and calcium distributions are nearly isotropic, vanadium and nickel have peaks in the direction (SE) of a fossil fuel power plant. Chromium has a peak in the distribution towards Miami International Airport, a site of industrial activity involving nonferrous metals. A small welding shop is located ~ 0.5 km south of site 10 and would account for the iron and nickel distribution peaks toward the south. The lead and bromine distributions are similar, with peaks to the east, traceable to automotive traffic on I-95

TABLE 8. RADII FOR POLAR PLOTS IN FIGURES 23 TO 33 (ng/m^3)

Element	Station 10	Station 11	Station 14
P	1404	-	1400
S	28	3143	2750
Cl	6875	698	1400
K	7	354	354
Ca	14	6875	3819
Ti	337	177	-
V	68	35	-
Cr	103	36	-
Mn	131	72	70
Fe	3667	1400	688
Ni	35	71	68
Cu	37	169	71
Zn	140	35	69
Br	1408	356	880
Pb	7028	1419	3536

TABLE 9. SITE 14 ANGULAR DISTRIBUTIONS

Element	Angle (degrees)	Probable Source	Distance (km)
S	160	Fossil fuel power plant (937 tons SO_2/year)	8
	225	Fuel oil dispersing	< 1
Cl	90-150	Sea spray	10
	200	Water purification plant	< 1
Ca	100-140	Construction (highway)	1
	225	Concrete dust	< 1
	330	Residential construction	2
Fe	90-135	Highway construction	< 1
	180	Welding, repair shop	< 1
Ni	225	Auto repair	< 1
Br,Pb	225	Automotive fuel dispensing, auto repair	< 1

north. Site 11 chlorine distributions lie primarily to the east and the potassium and calcium to the northwest toward quarrying operations. The peaks in the other elemental distributions are probably due to unidentified local sources.

FURTHER ANALYTICAL APPLICATIONS

The total mass of sulfur as measured by the cascade impactors may be used to deduce the amount of ammonium sulfate in the aerosol. The north-south ratio of ammonium sulfate is 0.88, while the observed ratios are 1.2 at site 10, 1.0 at site 11, but only 0.27 at site 14. (Tables 5 and 7) This suggests another sulfur source, possibly insecticide, near site 14.

A simple calculation based on hi-vol particulate data allows a qualitative explanation of the observed total particulate mass and is in agreement with the calculated emission factors for automobiles and fuel oil fly ash. According to the national emissions data system figures for 1975 (Epstein and Lynn 1976), the total particulate mass emitted in Dade County is 3×10^6 kg/year. Automobile particulates are 3.3×10^5 kg/year or 11 percent of the total, and fuel oil particulates are 3.4×10^5 kg/year, again 11 percent of the total. These figures are in reasonable agreement with the calculated automobile emission factors of 5.8, 7.7, and 2.7 percent at stations 10, 11, and 14, respectively (Table 6). Calculated fuel oil fly ash emission factors are 2.7, 4.5, and 6.5 percent at sites 10, 11, and 14, respectively.

SECTION 5

SITE-BY-SITE SUMMARY

SITE 10

The elemental size distributions for site 10 indicate that Br and Pb result primarily from combustion sources, (i.e., small-particle-favored distributions), while the elements Cl, K, Ca, Ti, and Fe exhibit large-particle-favored distributions typical of abrasive sources. Bimodal distributions are exhibited by P, S, V, Cr, Mn, Ni, and Zn, indicating multiple sources. No significant difference is observed in the shape of the size distributions for the two data sets. The mass weighted mean diameter data averaged for 6/2, 6/3, and 6/4 indicate that Cl, K, Ca, and Fe are from abrasive sources, while S, Ti, Cr, Br, and Pb are from combustion type sources. The data averaged for 6/11 and 6/12 indicate that Cl, K, Ca, Cr, and Zn are from abrasive sources, while S, Ni, Cu, Br, and Pb are from combustion type sources. This information indicates that Cl, K, and Ca are primarily from abrasive sources, while S, Br, and Pb are primarily from combustion sources. The remaining elements would appear to be from multiple sources.

The mass weighted mean diameter values taken from the wind-direction-sensitive size distribution data (Table 3) indicate small-particulate sources for P, Cl, K, and Ca are located northwest of the sampling site, and Pb has a large-particulate source southwest of the sampling site. The distribution shape for the other elements is similar for the four sectors sampled.

The elemental directional distribution data show that S, Cl, and K sources lie southeast of the sampling site. Ca is distributed uniformly except for a peak in the northwest direction, toward several cement manufacturing facilities.

The Ti distribution has prominent peaks in the southeast, south, and northwest directions. Numerous auto repair and painting facilities are located on 27 Avenue, south of the sampling site; and auto repair, paint, and metal fabricators are northwest of the sampling site. Elements V, Cr, Mn, Fe, Ni, and Zn have peaks in the southeast direction, toward the downtown area, and other peaks generally in the southerly and northwesterly direction. Source identification is difficult at site 10 because of the variety of industries located west of the sampling site. Figure 34 shows the location of these industries relative to the sampling site. Lead and bromine distribution peaks could be caused by automotive activity at the corner of 32 Avenue and 71 Street (Figure 35).

The time distribution of the elements measured is shown in Figures 17 to 22. Levels of S and Cl on 6/8 and 6/9 increased slightly when the inversions in the morning were strong. The sharp peaks in the distribution of Fe, Br, and Pb do not seem to be correlated with weather conditions, but the increase in Zn concentration occurred when a temperature inversion persisted all day.

The traffic count on 27 Avenue adjacent to the sampling station is shown in Figure 19. A remarkable feature of the Pb and Br time distributions is the lack of correlation with the traffic count on the adjacent roadway.

The source coefficients calculated from the elemental data do not agree with the conclusions from microscopical data analysis (Draftz 1979). The elemental data indicate that the primary aerosol components at site 10 were caused by the reentrainment of soil and cement dust into the atmosphere, possibly by automotive activity; minor components appear to have been contributed by salt spray, automotive emissions, and fuel oil fly ash. Light industrial activity to the south, west, and north of the sampling site contributes heavily to the levels of elements such as Ti, V, Cr, Mn, Fe, Ni, and Zn. Levels of Pb and Br at the site are not resultant of traffic on 27 Avenue, adjacent to the sampling site; they are more likely caused by transportation associated with the industrial park, west of the sampling site, and traffic on I-95, east of the sampling site.

SITE 11

The elemental size distributions at site 11 indicate that Cl, Ca, and Fe are large-particle-favored distributions typical of abrasive sources. V, Cr, Mn, Br, and Pb size distribuirons are typical of combustion sources. The size distribution of sulfur indicates that a large-particle source of sulfur contributes to the aerosol at site 11. P, K, Ti, Ni, and Zn exhibit bimodal distribution typical of multiple sources. The Cu size distribution indicates a source of Cu particulates in the 1 to 2 μm range close to the sampling site.

The mass weighted mean diameter shown in Table 2 indicates that Cl, Ca, and Ni are primarily from abrasive sources; while S, V, Cr, Cu, Br, and Pb are from combustion sources. The mass weighted mean diameter is similar on both sampling days, with the exception of Mn, indicating a small particulate source influenced the size distribution for the 6/5 sample set.

The observed elemental directional distribution indicates a strong source(s) of S, K, Ca, V, Mn, Fe, and Zn to the northwest of the sampling site. Cl is primarily from the east, as would be expected. A Ti source is located northeast of the sampling site, while Br and Pb originate primarily from the west. Interpreting these data is difficult, since the sampling site was located adjacent to a school shop where various industrial activities, such as welding and auto repair, are taught. Figure 36 depicts possible sources near the sampling site; Figure 37 is a photograph of the sampling site.

The time distribution of the elements is featureless, with the exception of higher Cu levels at site 11 than at the other two sampling sites. The Cu levels are higher during the day from Monday through Friday, dropping on the weekend. The probable source is high school shop activity.

The source coefficients calculated for site 11 indicate that fuel oil fly ash, auto emissions, and sea spray constitute a minor component of the aerosol observed at this site. Primary components are soil and limestone dust, possibly related to the cement manufacturing activities west of the sampling site. The elemental analysis agrees in general with the microscopical analysis of the

samples at site 11 (Draftz 1979). However, elemental analysis indicates the primary aerosol component is reentrained soil dust, probably from general activity in the area rather than from automobiles in particular. Both microscopy and elemental analysis indicate a higher contribution from automobiles at site 11 than at site 10.

SITE 14

The elemental size distributions of P, Cl, K, Ca, Ti, Mn, and Fe are typical of abrasive sources. The size distributions of S and V are typical of combustion-type sources. Ni, Cu, Zn, Br, and Pb elemental size distributions are bimodal, indicating two distant sources. The size distribution of Ti, Ni, and Cu were markedly different for the two samples analyzed. The Cu size distribution observed for the 6/5 sample indicates a Cu particulate source in the 1 to 2 μm range. This source was not observed in the 6/12 sample set. The size distribution of Br and Pb are unusual and not typical of tail pipe emissions. The mass weighted mean diameter data from Table 2 indicate that Cl, K, Ca, Mn, and Fe are large-particulate-favored size distributions and S and V are small-particle-favored size distrbutions. The analysis of the directional distribution of particulate matter at site 14 is simplified, because the sampling site is in a primarily residential area. Table 9 identifies possible sources for the elements and their distance from the sampling site. Figure 38 is a map of possible sources near the sampling site; Figure 39 is an aerial photograph of the site. During the sampling period, the freeway southeast of the sampling site was under construction. The prominent peaks in the Cu and Zn distributions are most likely produced by this freeway construction activity.

The elemental time distributions show higher levels of elements S, Cl, K, Ti, V, Cr, Mn, Fe, and Ni on 6/8 and 6/9 when strong inversions were observed in the morning (Table 1), suggesting that sources for these elements are not close to the sampling site. The peaks in the Cu and Zn time distributions at ~ 2400 on 6/6 indicate a local source for these two elements. The same correlation is observed with Br and Pb on 6/7 and with Cu and Zn on 6/16.

The source coefficients calculated for site 14 indicate the primary source of aerosol at site 14 is soil dust, attributable to local construction activity. The sea spray contribution here approximates that at site 11, while the automotive contribution is about one-half that of the other two sites, as would be expected. The fuel oil fly ash contribution is higher because of a nearby fossil fuel power plant.

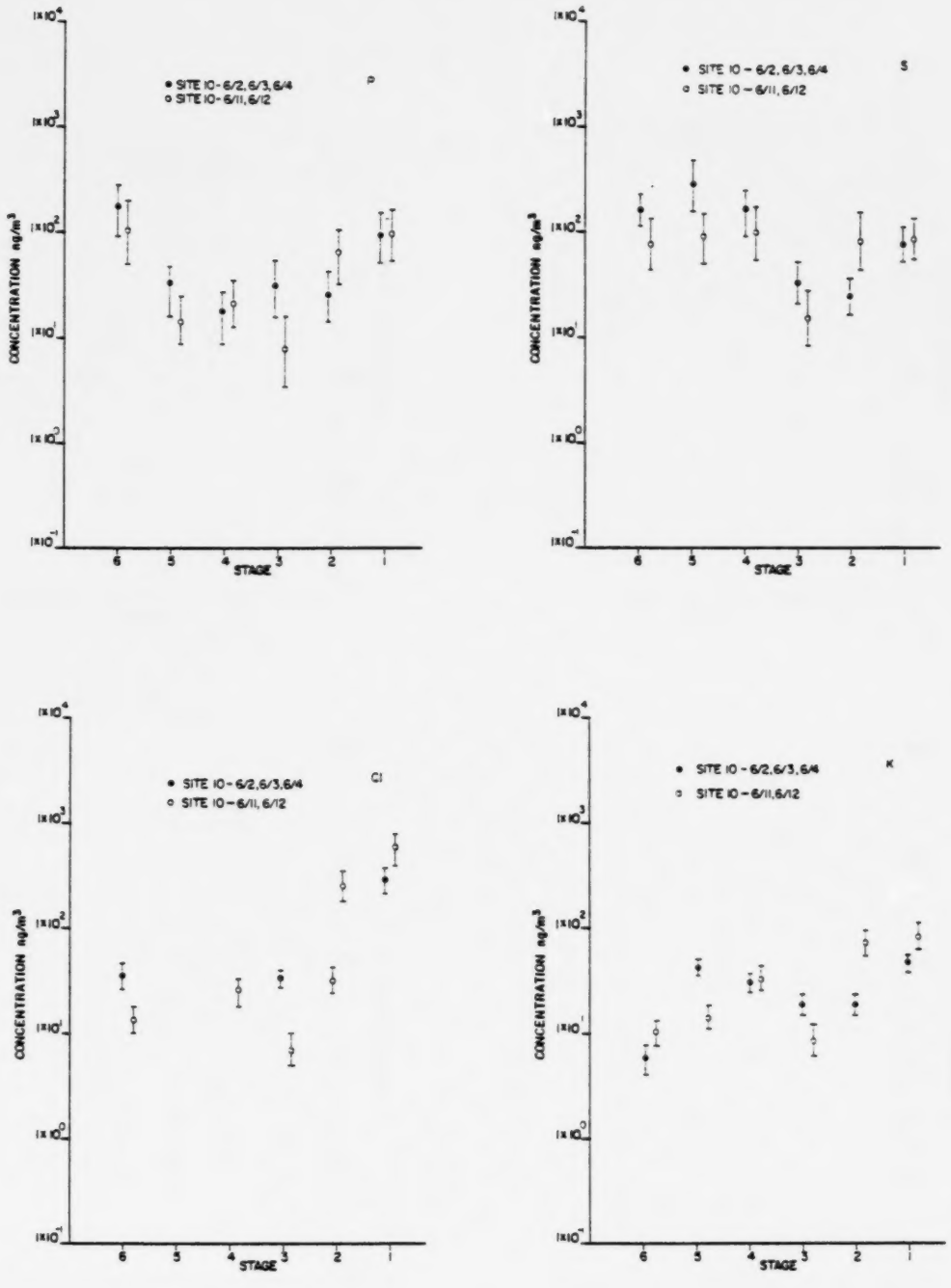


Figure 2. Size distribution data for P, S, Cl, and K at site 10.

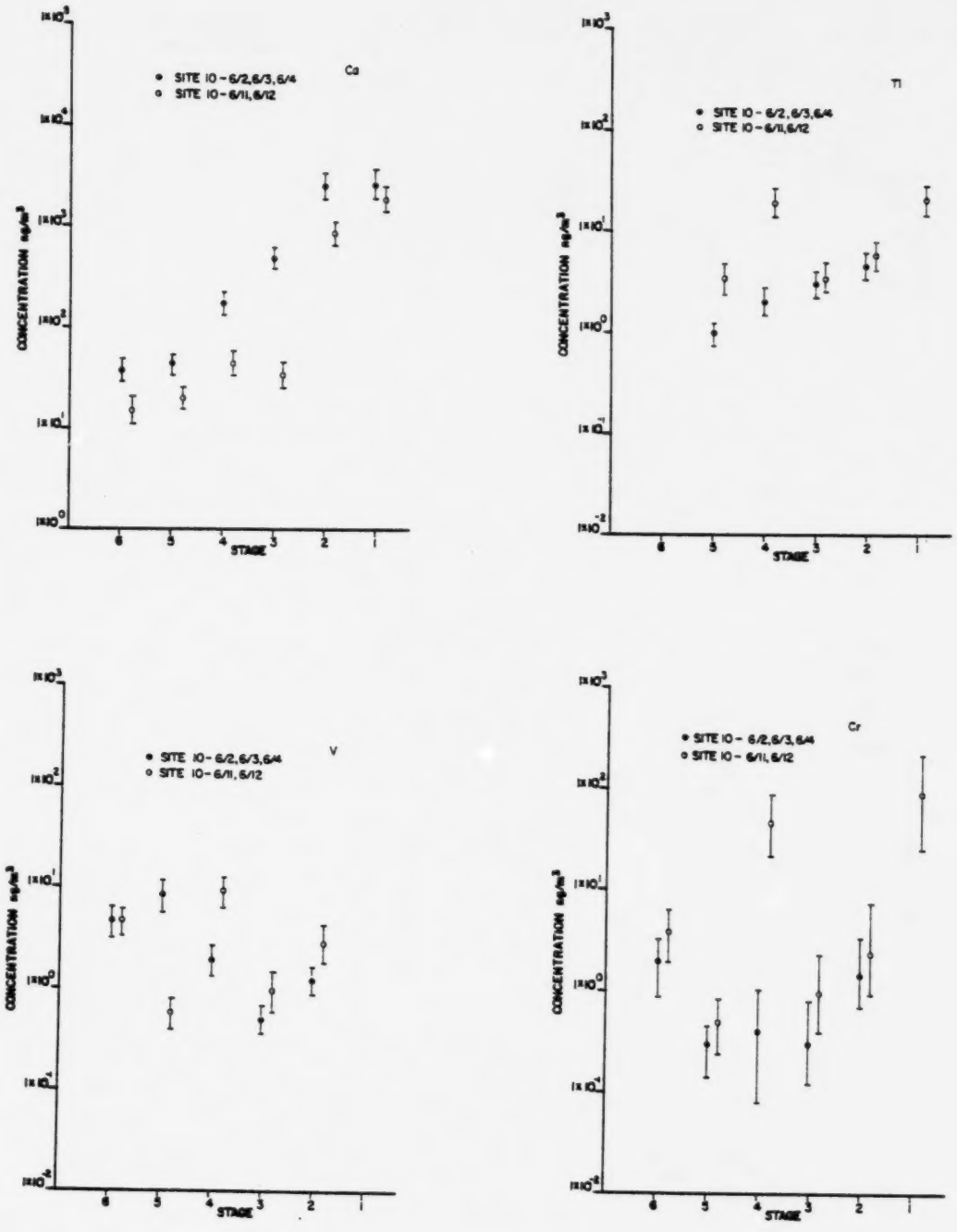


Figure 3. Size distribution data for Ca, Ti, V, and Cr at site 10.

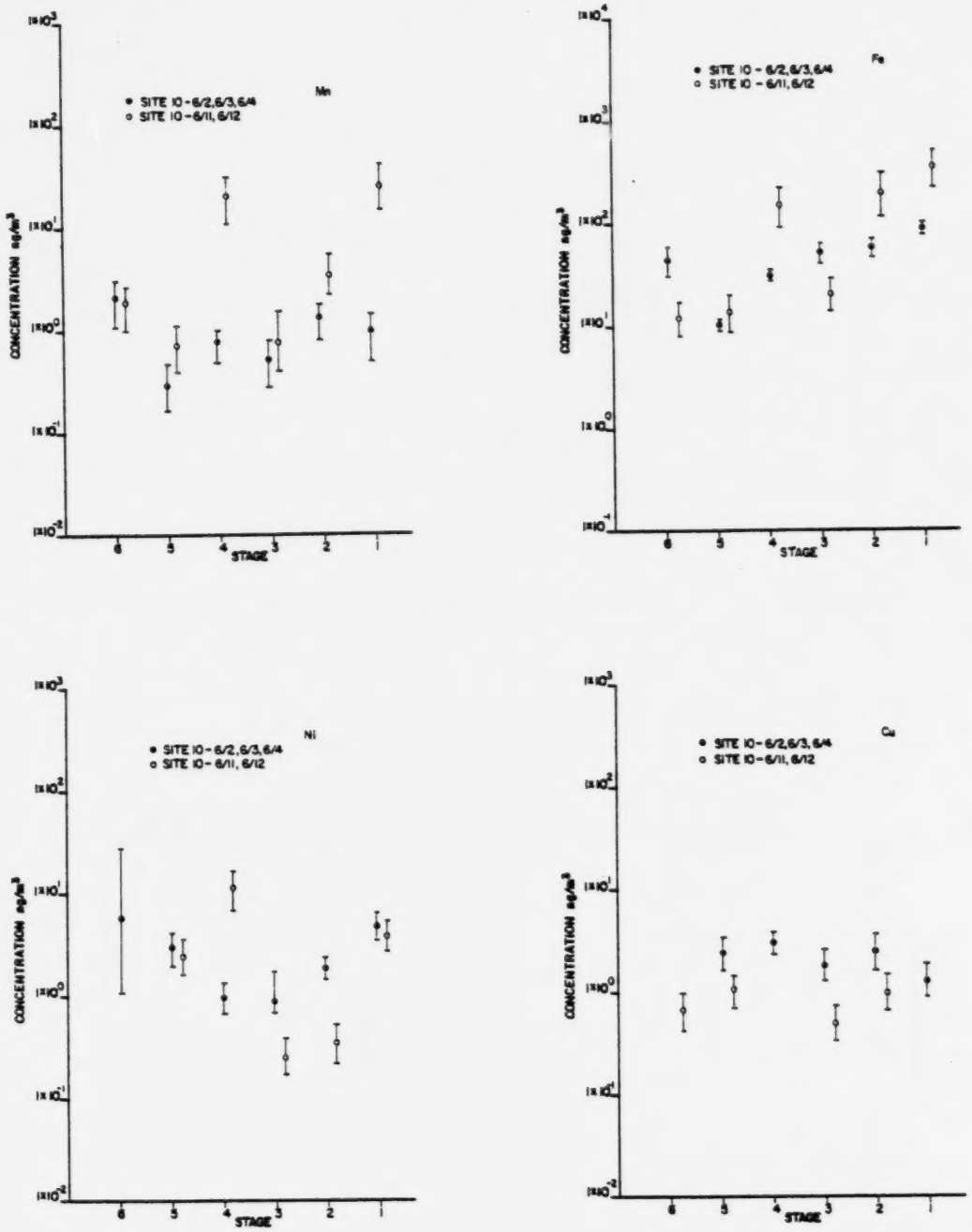


Figure 4. Size distribution data for Mn, Fe, Ni, and Cu at site 10.

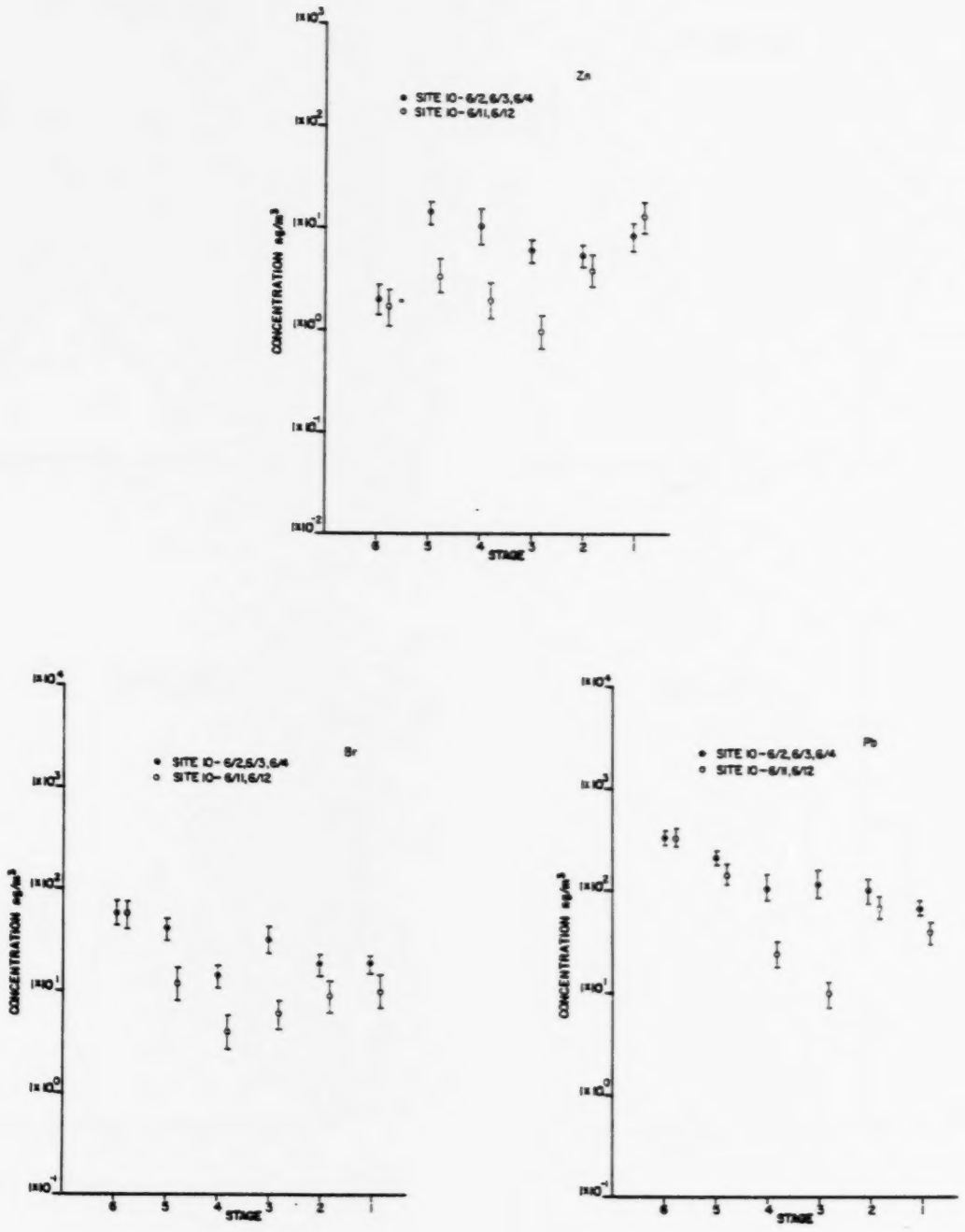


Figure 5. Size distribution data for Zn, Br, and Pb at site 10.

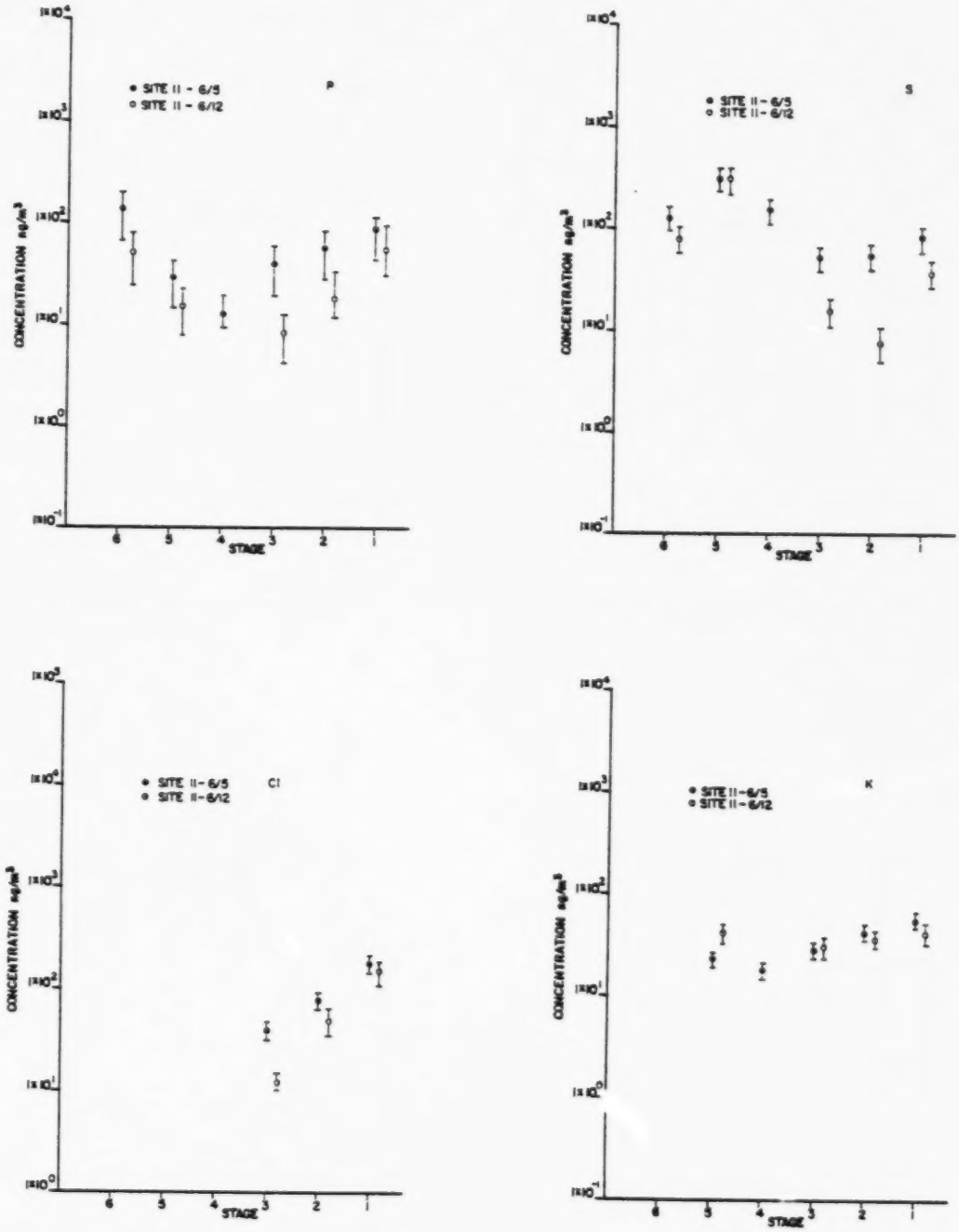


Figure 6. Size distribution data for P, S, Cl, and K at site 11.

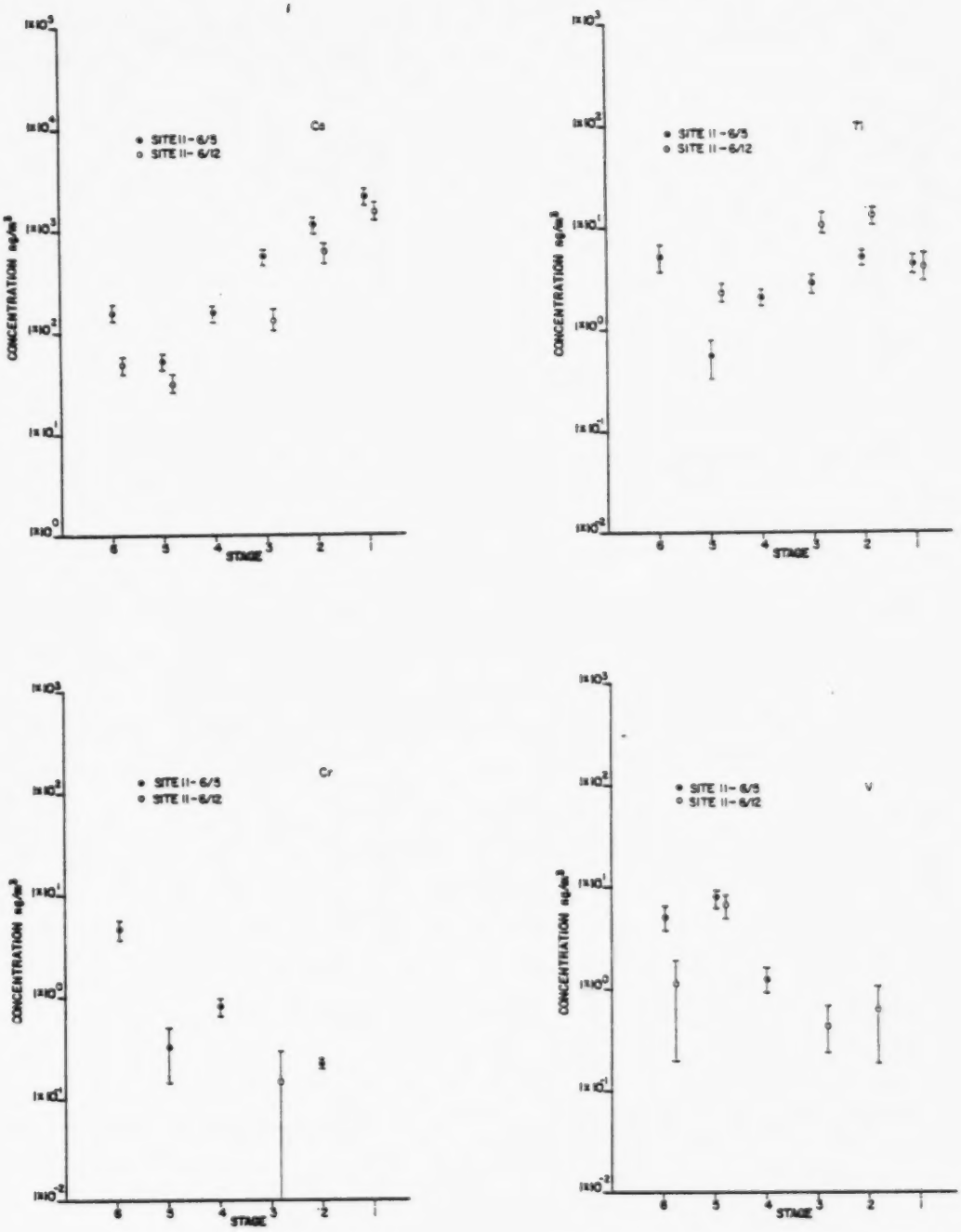


Figure 7. Size distribution data for Ca, Ti, V, and Cr at site 11.

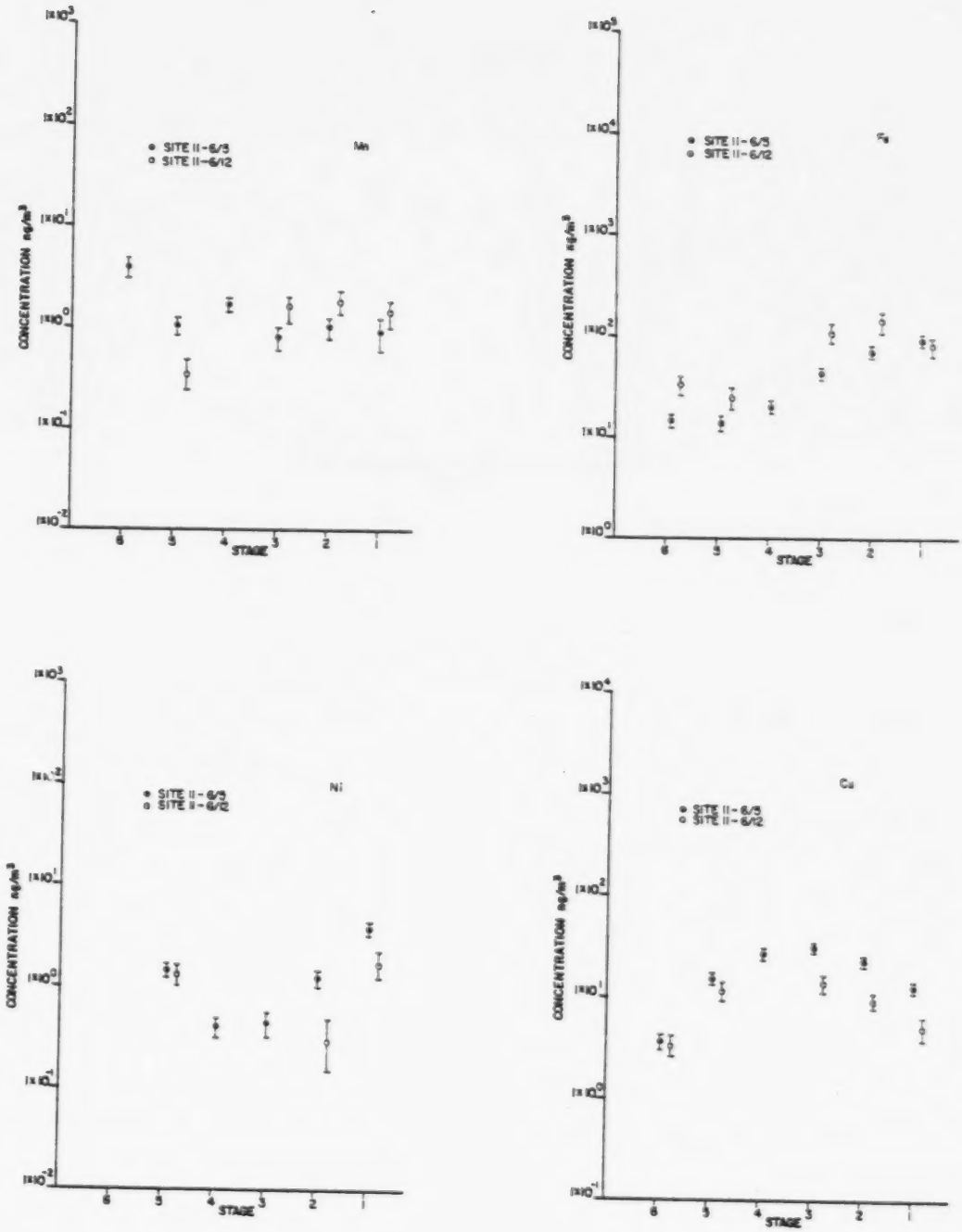


Figure 8. Size distribution data for Mn, Fe, Ni, and Cu at site 11.

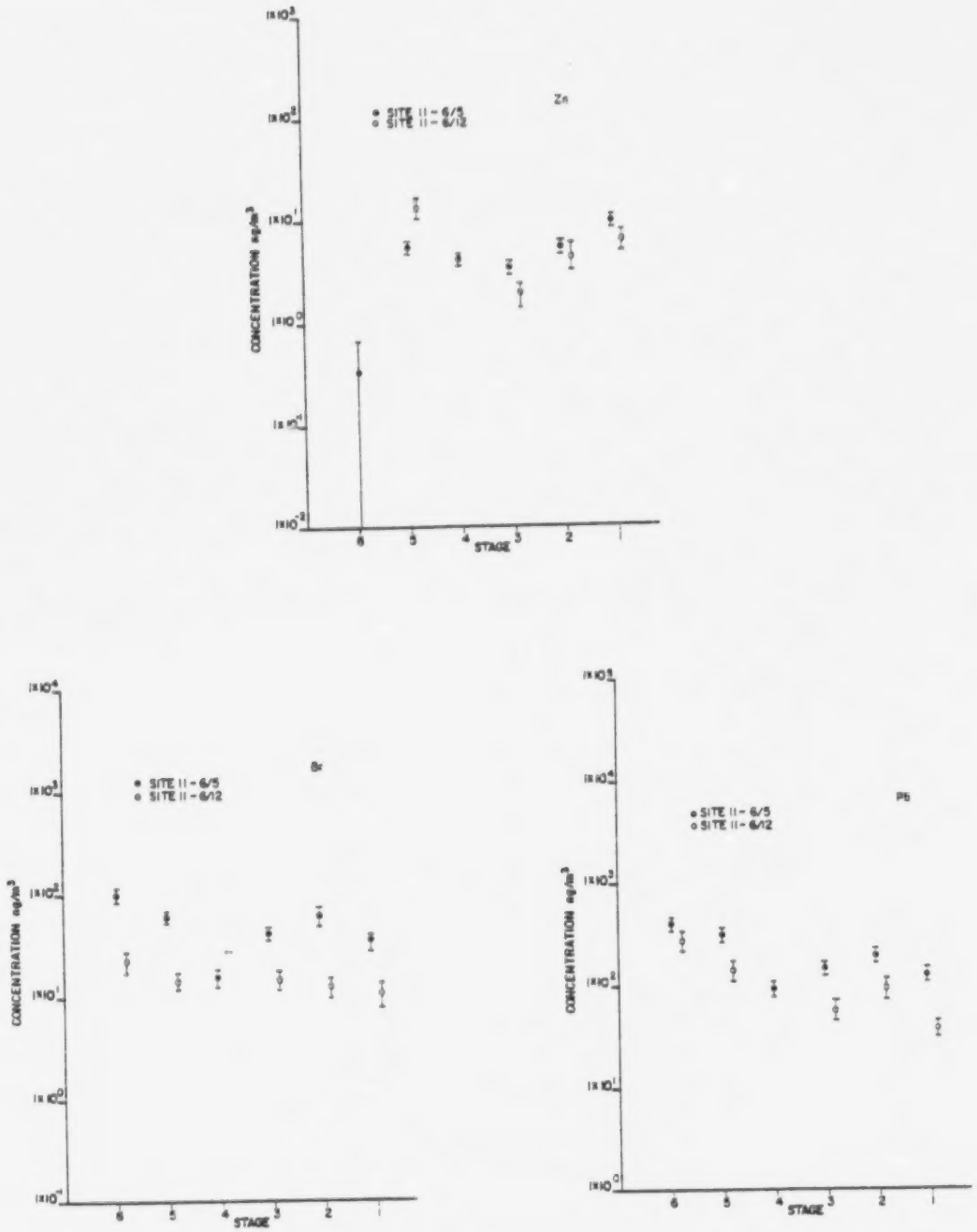


Figure 9. Size distribution data for Zn, Br, and Pb at site 11.

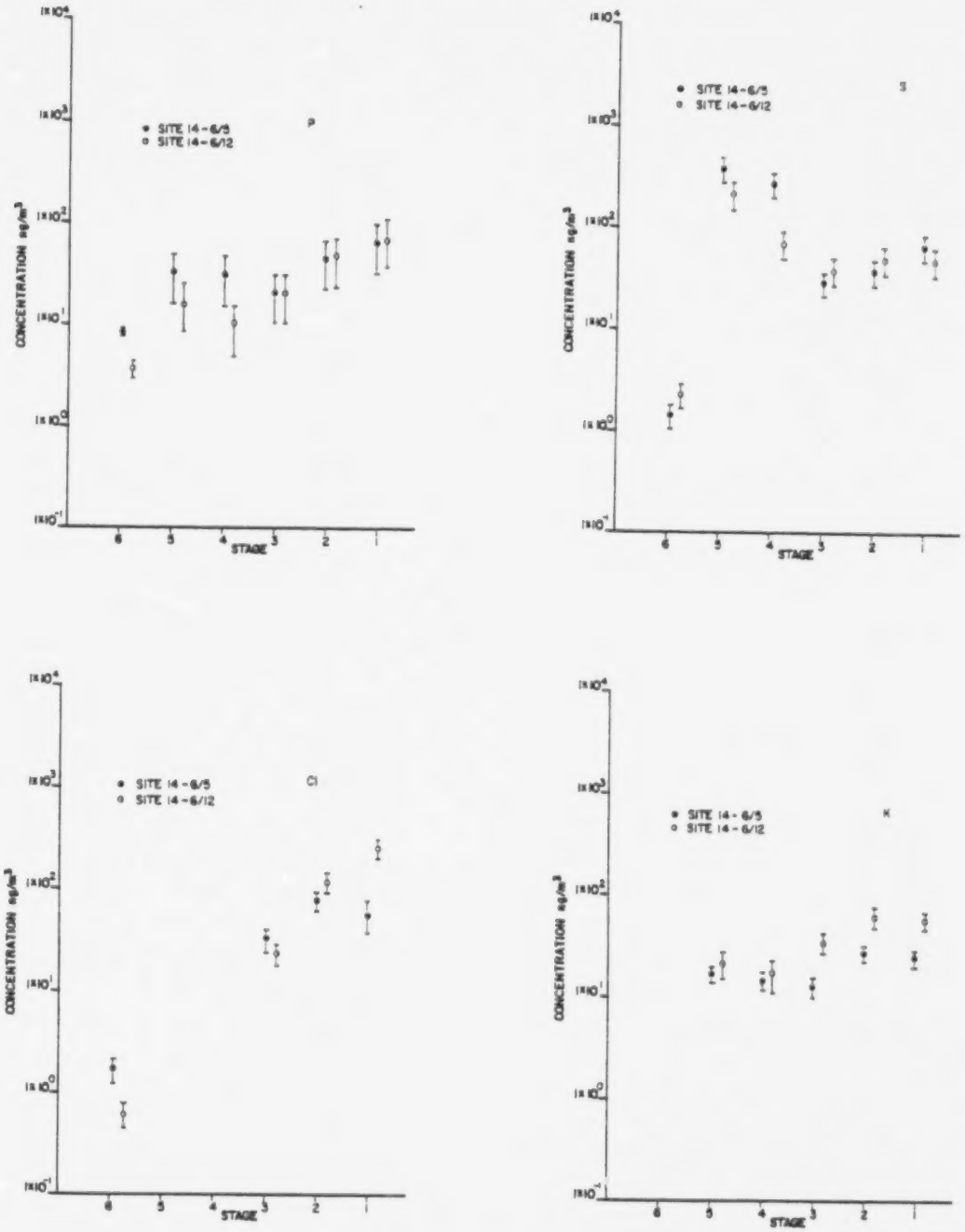


Figure 10. Size distribution data for P, S, Cl, and K at site 14.

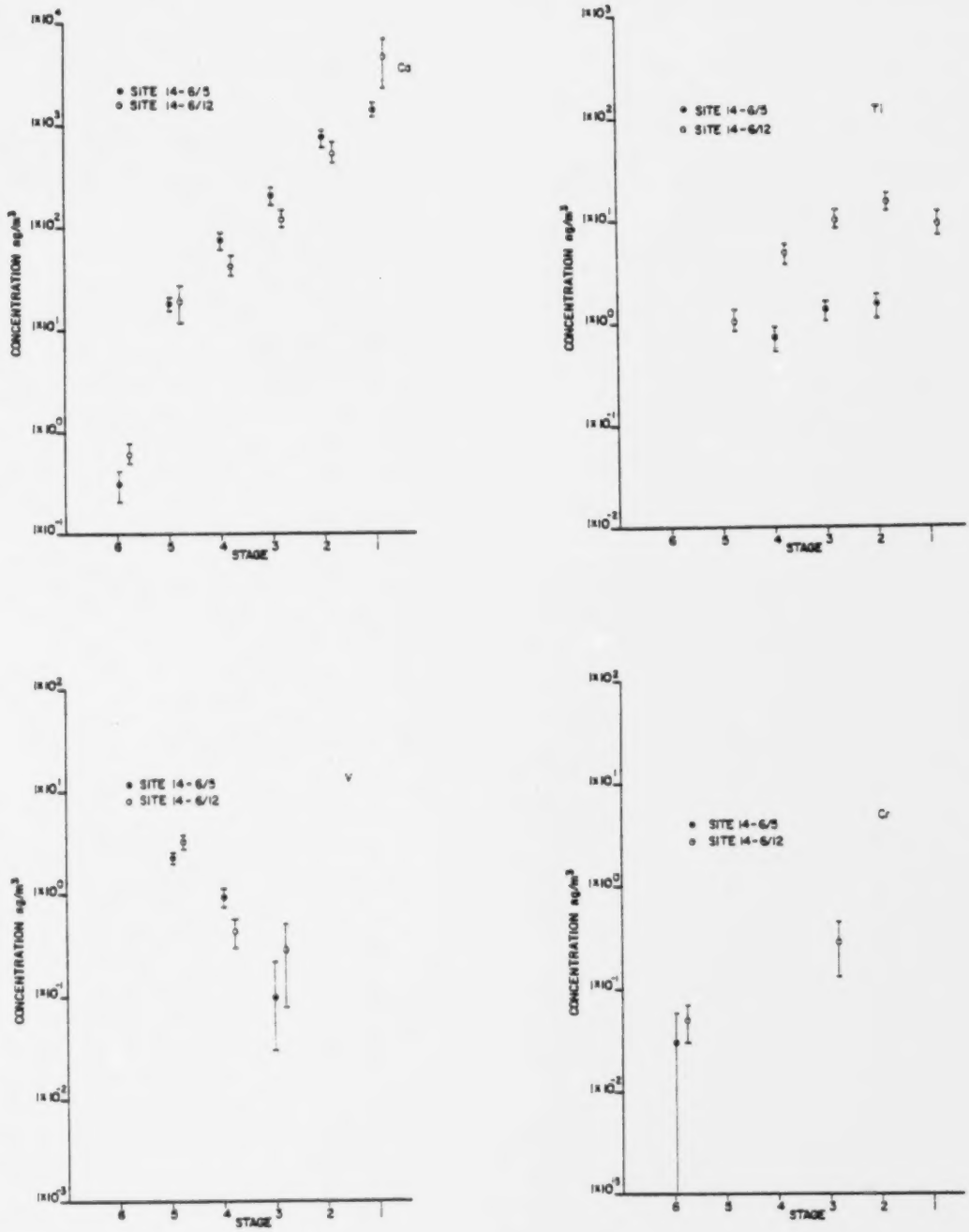


Figure 11. Size distribution data for Ca, Ti, V, and Cr at site 14.

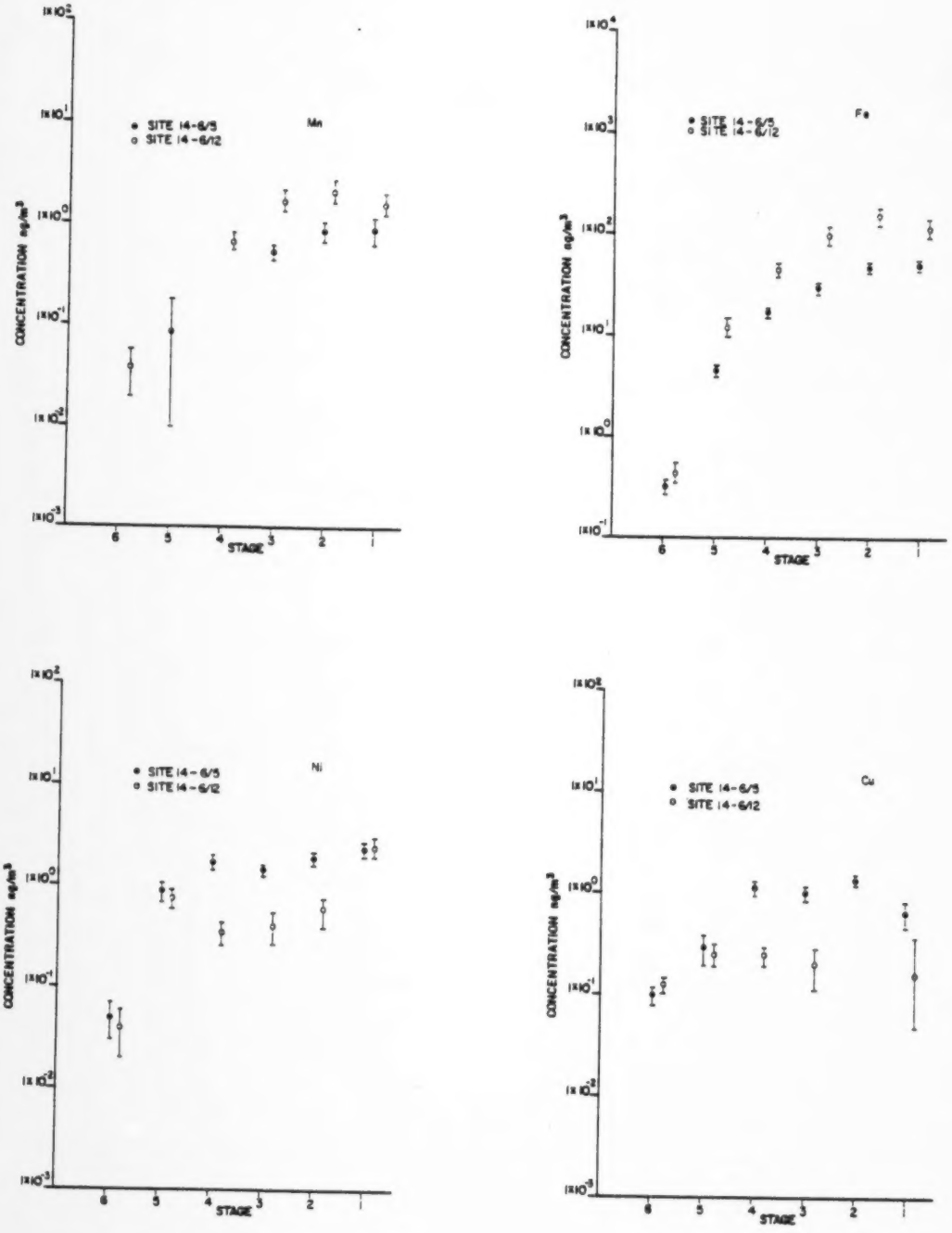


Figure 12. Size distribution data for Mn, Fe, Ni, and Cu at site 14.

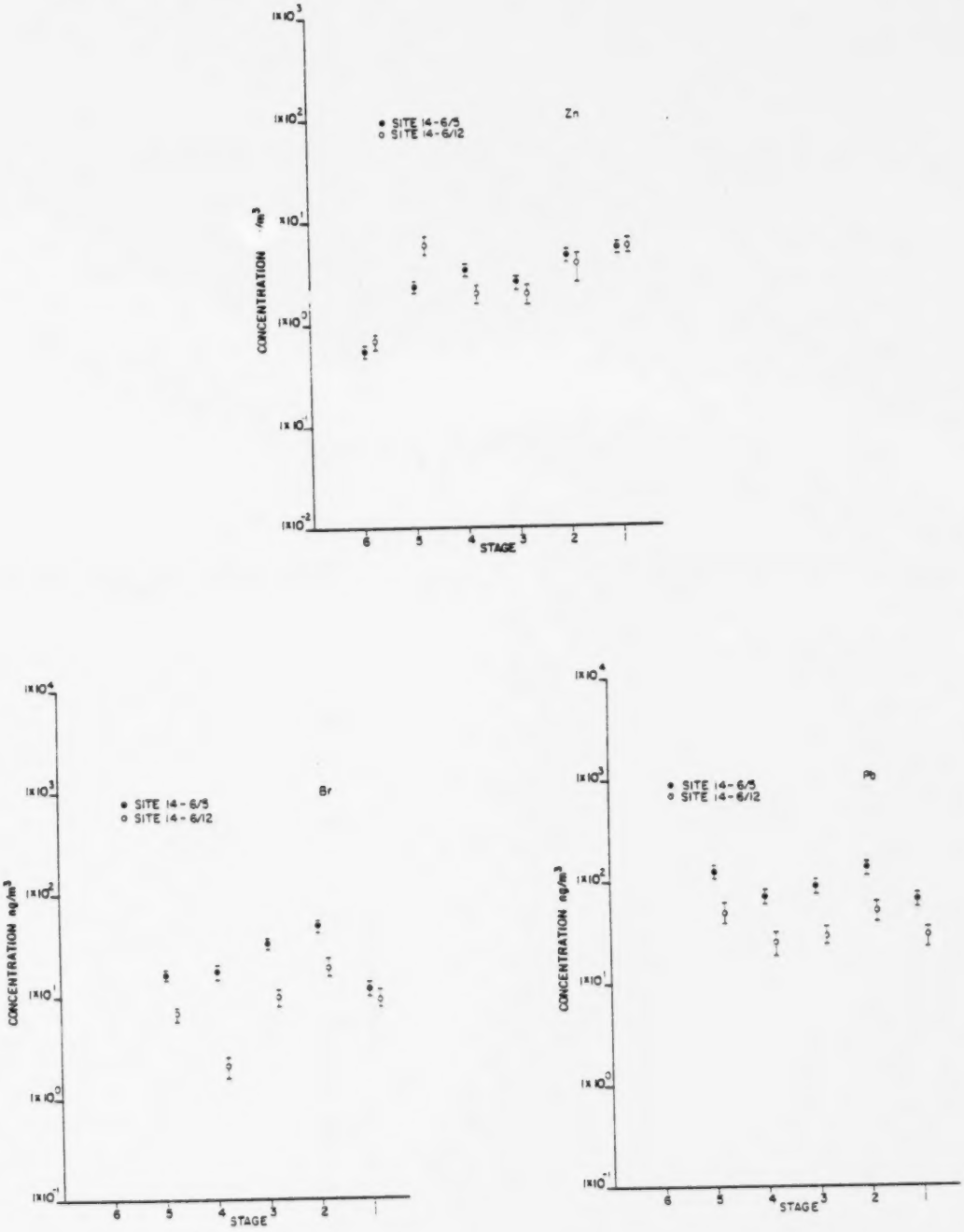


Figure 13. Size distribution data for Zn, Br, and Pb at site 14.

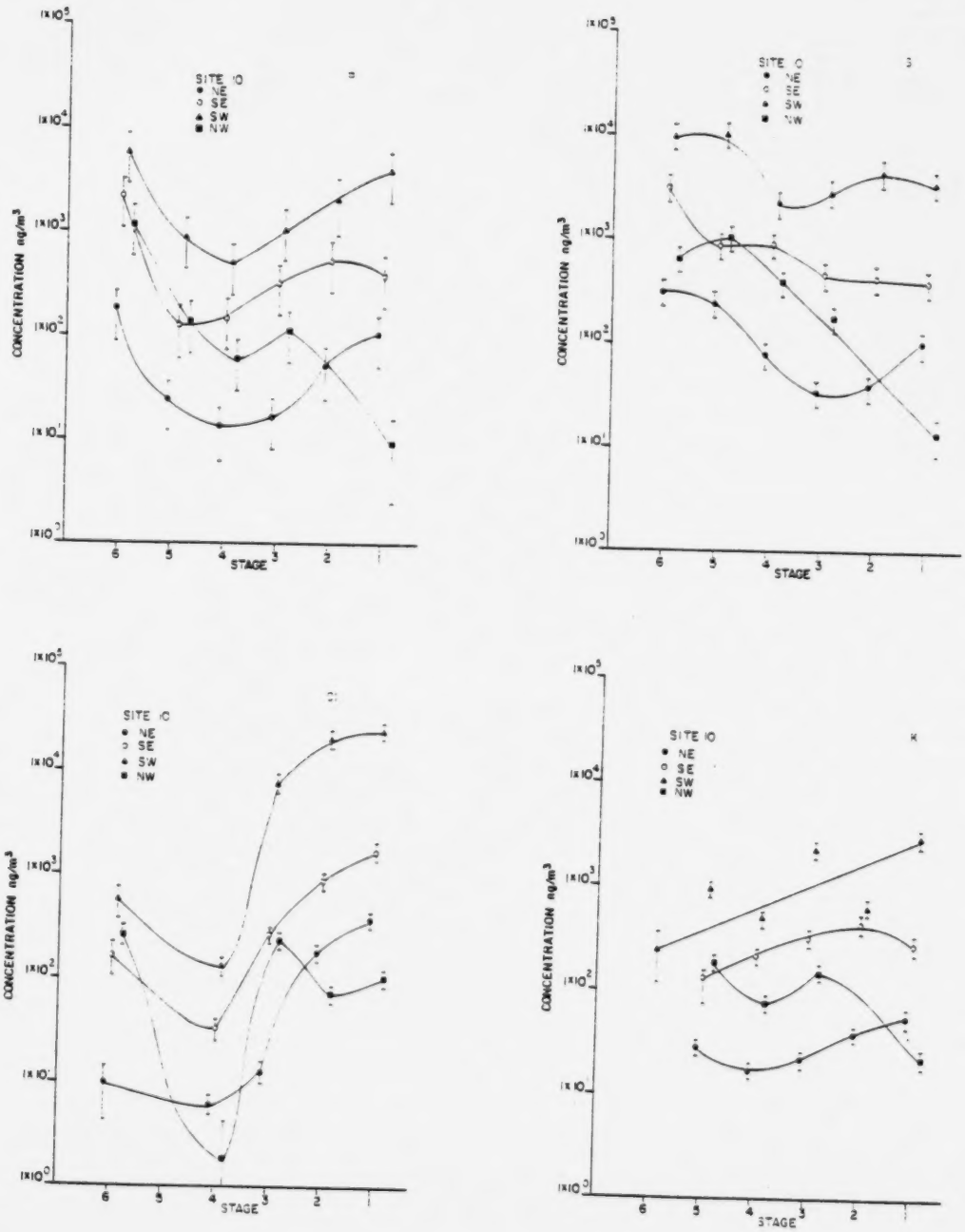


Figure 14. Size distribution of P, S, Cl, and K, as a function of wind direction.

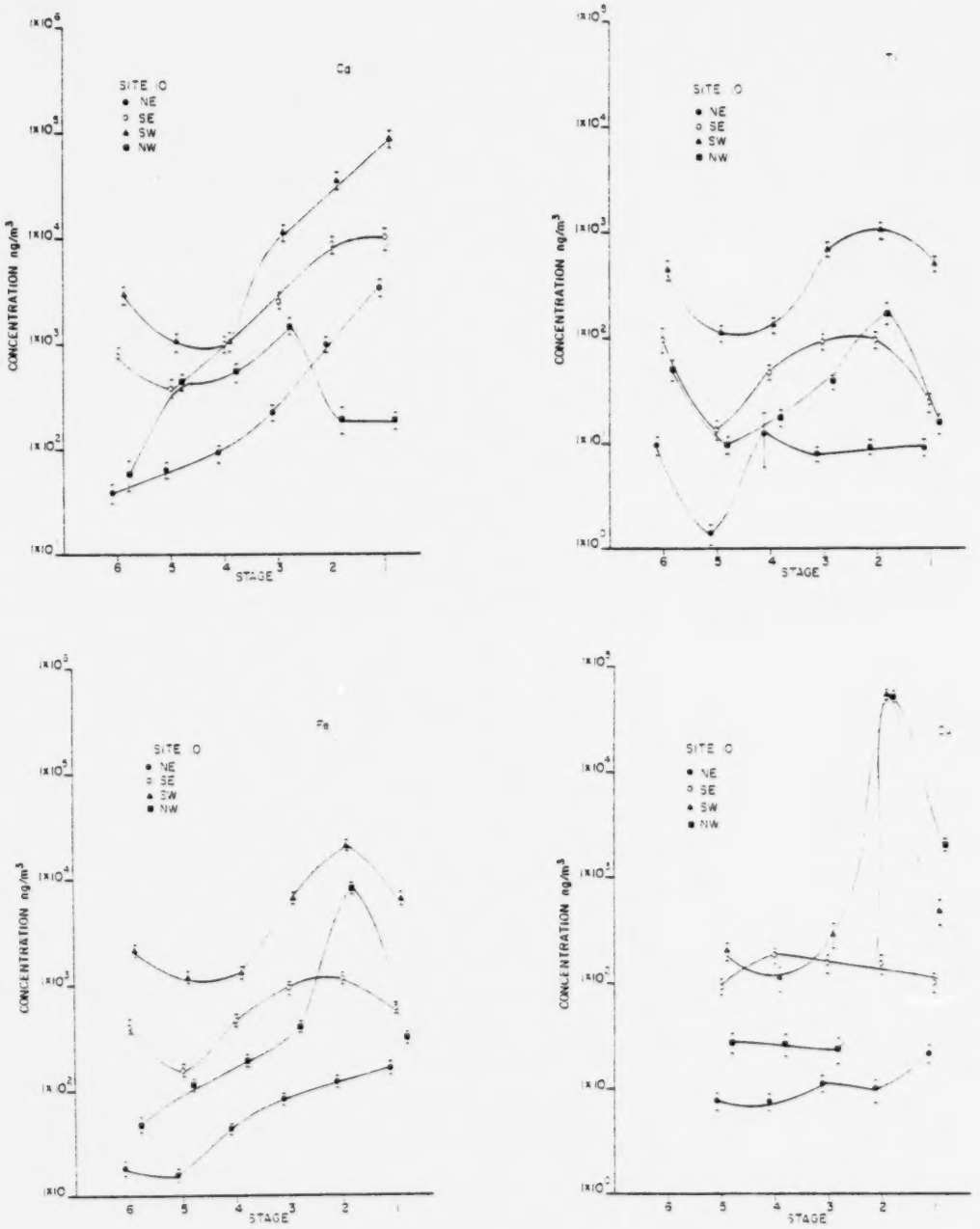


Figure 15. Size distribution of Ca, Ti, Fe, and Cu, as a function of wind direction.

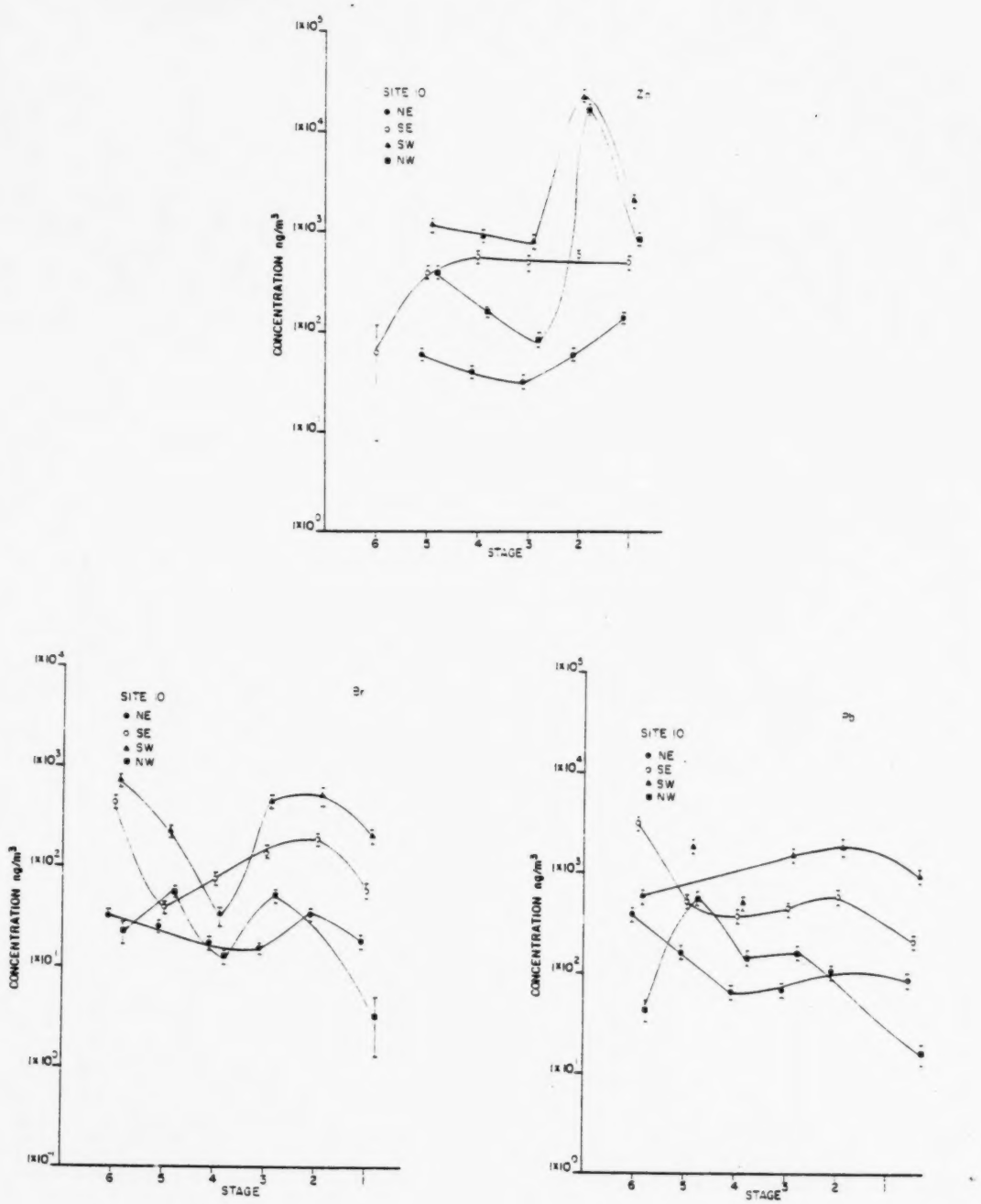


Figure 16. Size distribution of Zn, Br, and Pb, as a function of wind direction.

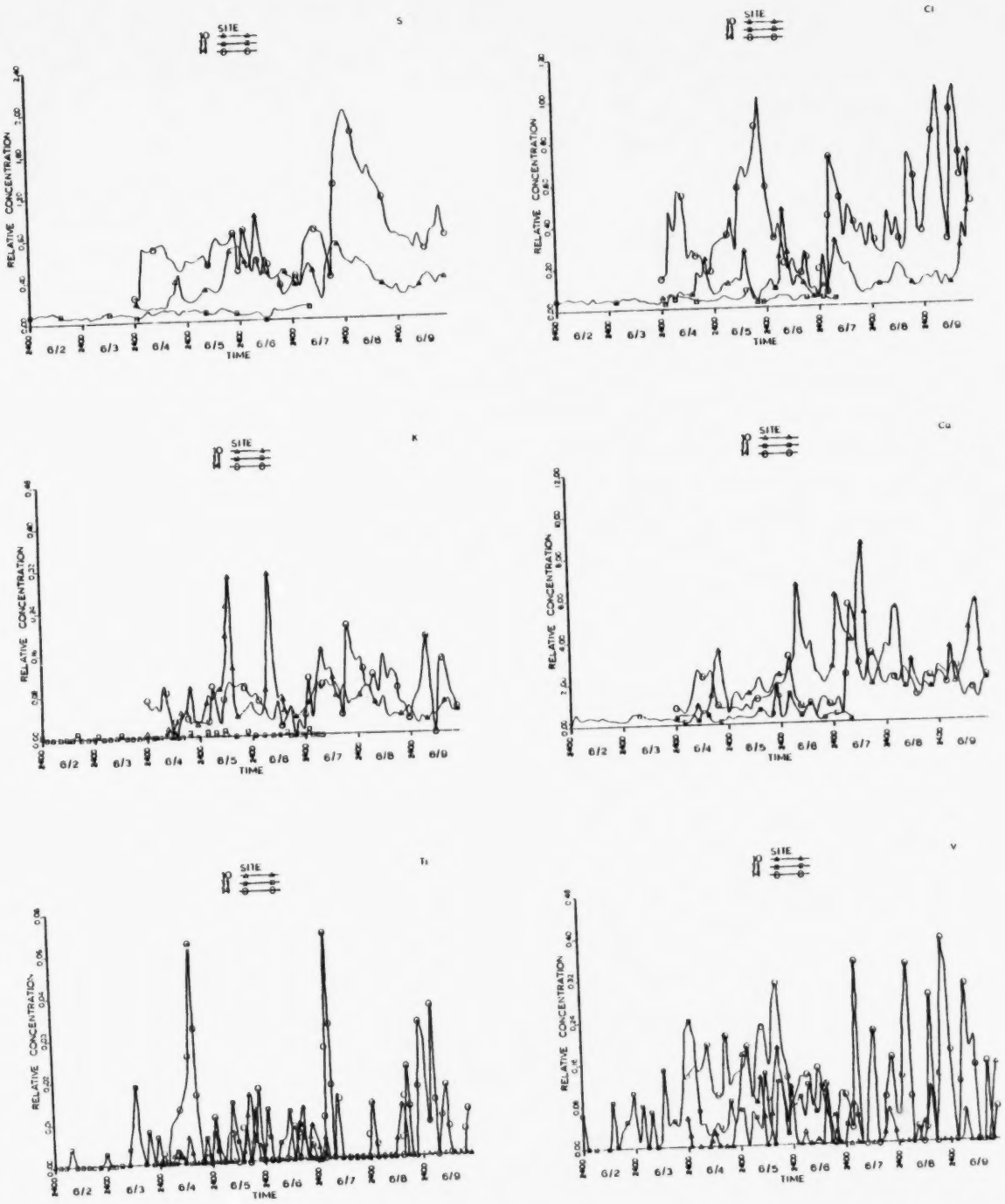


Figure 17. Time distribution of S, Cl, K, Ca, Ti, and V, at sites 10, 11, and 14, 6/2/75 to 6/9/75.

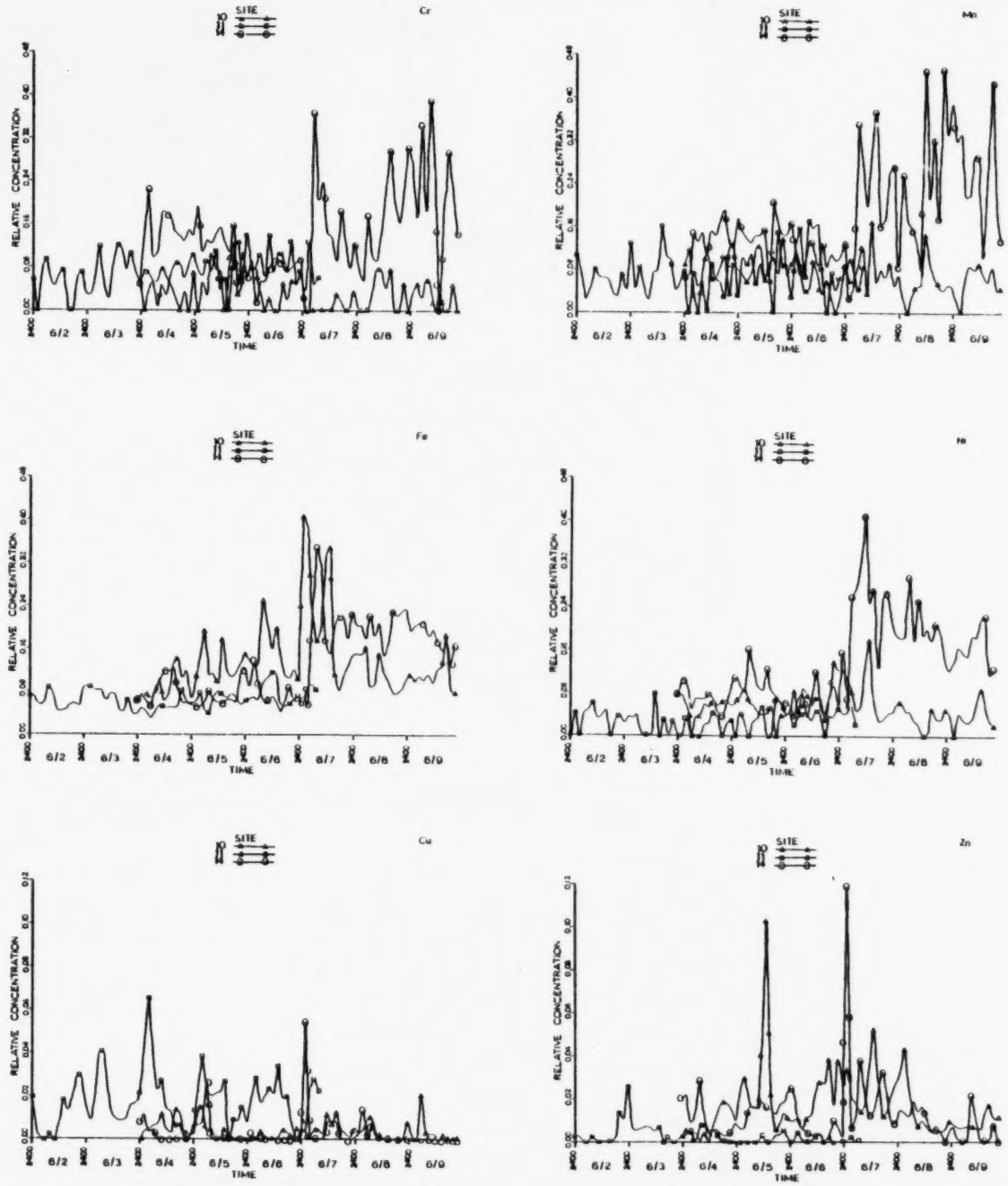


Figure 18. Time distribution of Cr, Mn, Fe, Ni, Cu, and Zn, at sites 10, 11, and 14, 6/2/75 to 6/9/75.

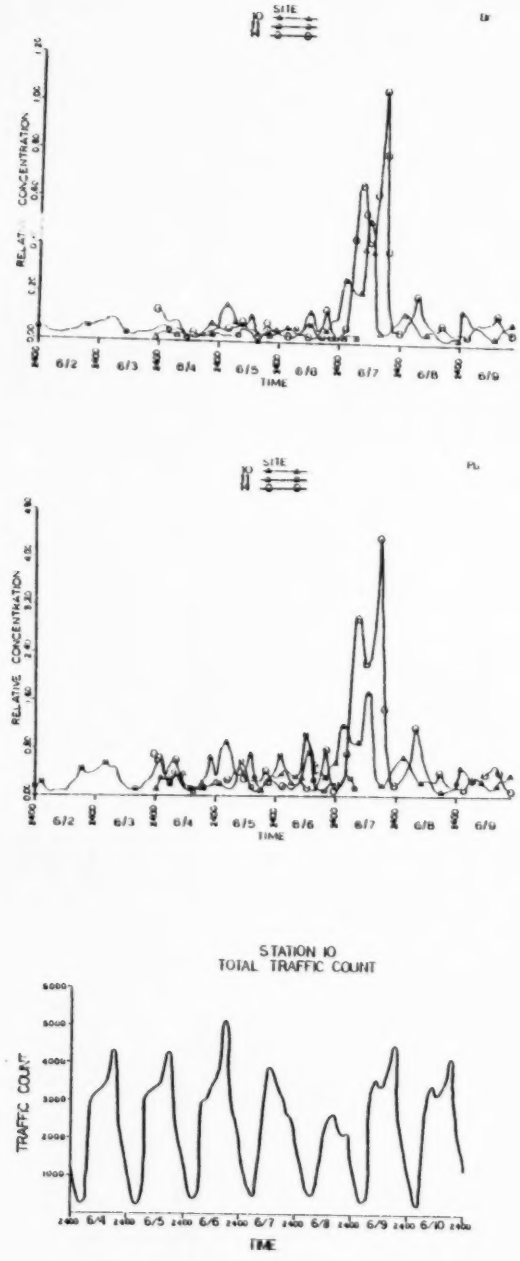


Figure 19. Time distribution of Br and Pb at sites 10, 11, and 14, 6/2/75 to 6/9/75; and traffic count at site 10, 6/4/75 to 6/10/75.

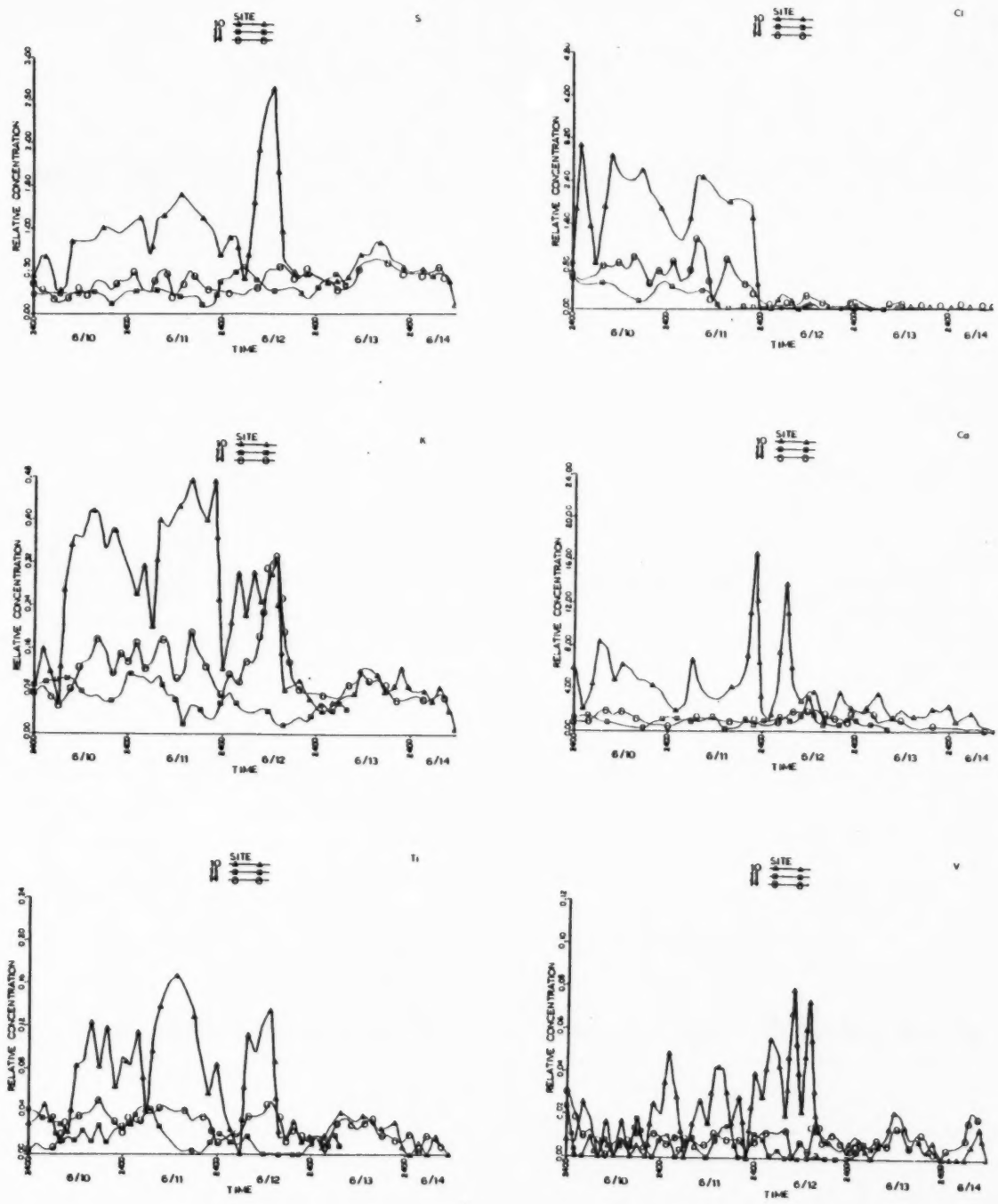


Figure 20. Time distribution of S, Cl, K, Ca, Ti, and V, at sites 10, 11, and 14, 6/10/75 to 6/14/75.

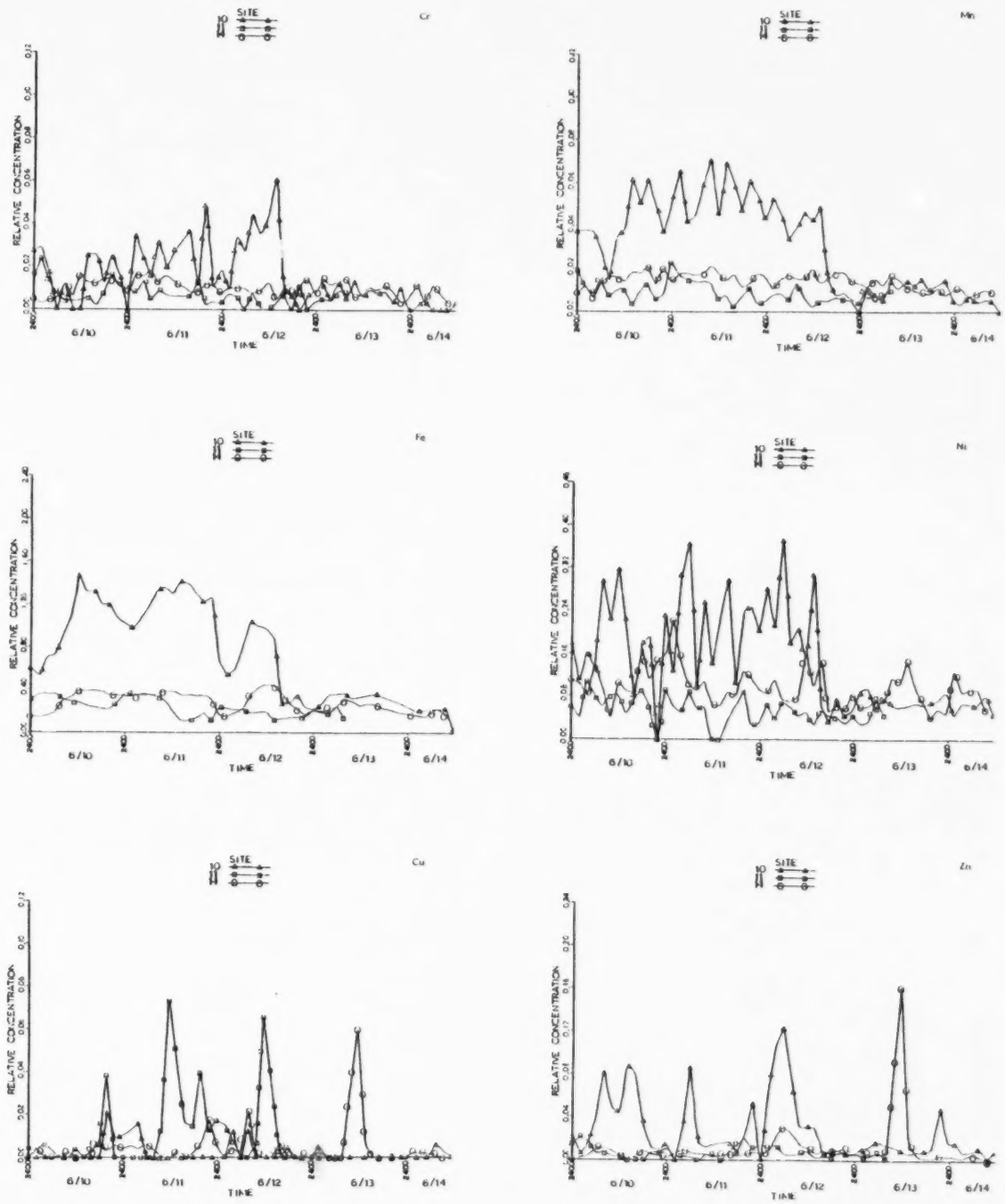


Figure 21. Time distribution of Cr, Mn, Fe, Ni, Cu, and Zn, at sites 10, 11, and 14, 6/10/75 to 6/14/75.

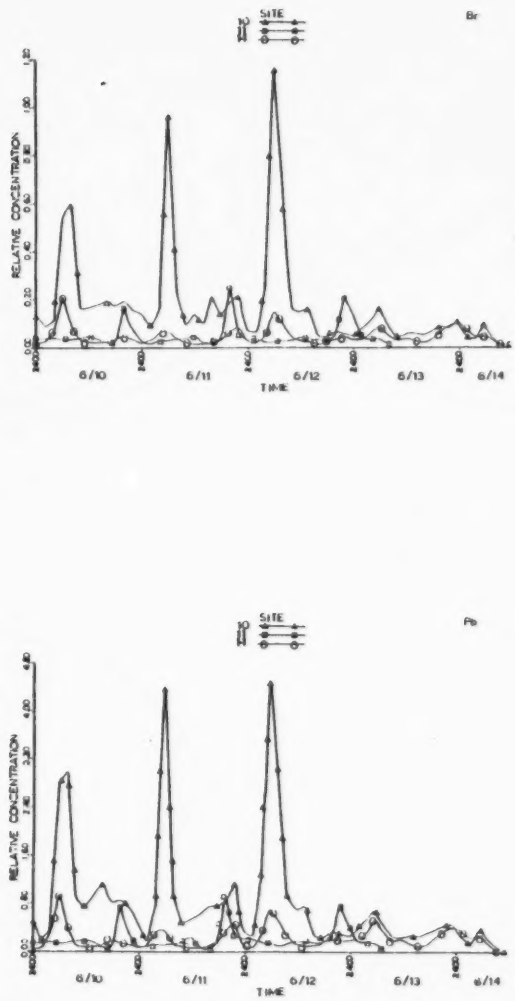


Figure 22. Time distribution of Br and Pb at sites 10, 11, and 14, 6/10/75 to 6/14/75.

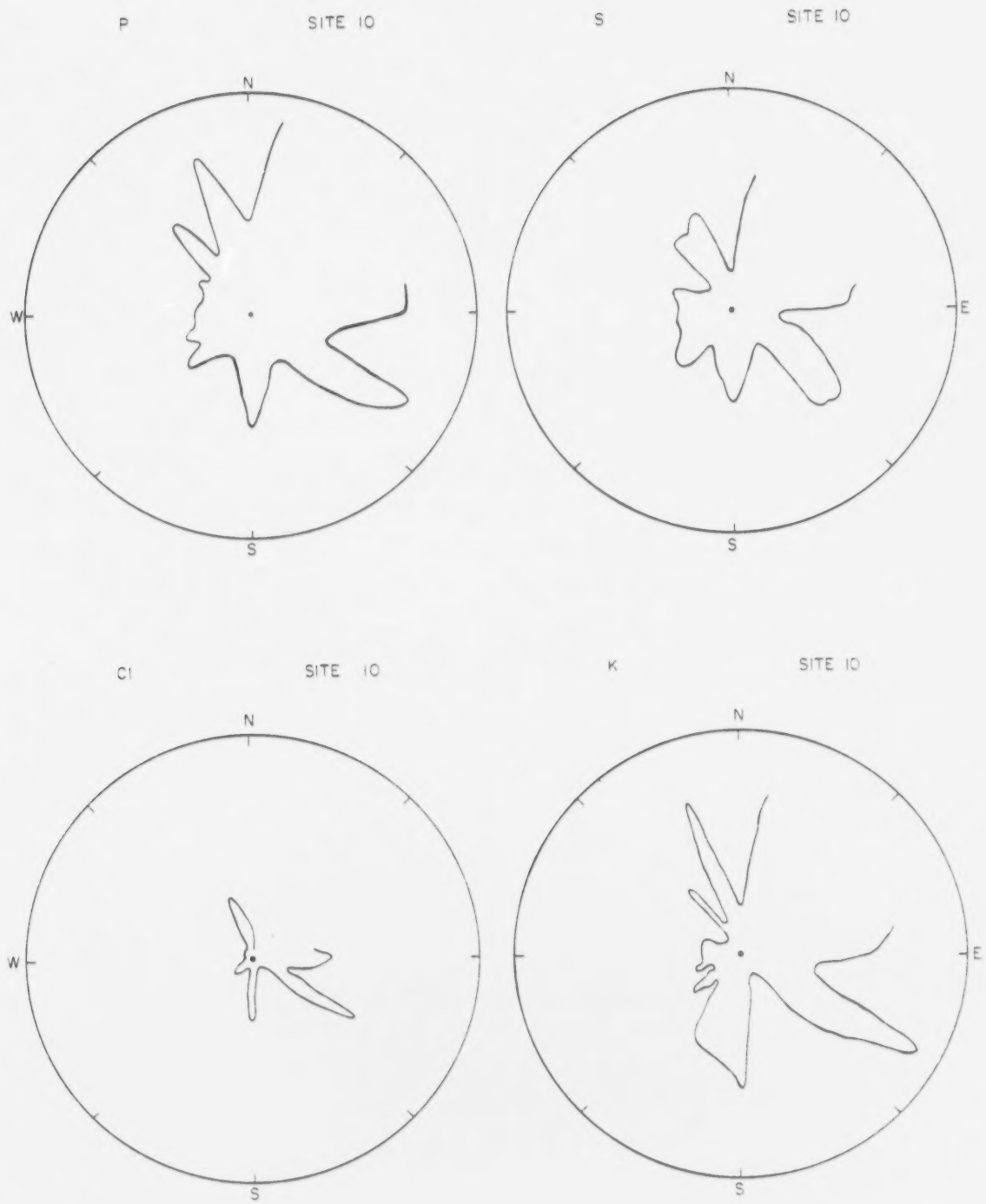


Figure 23. Angular distribution of P, S, Cl, and K, site 10.

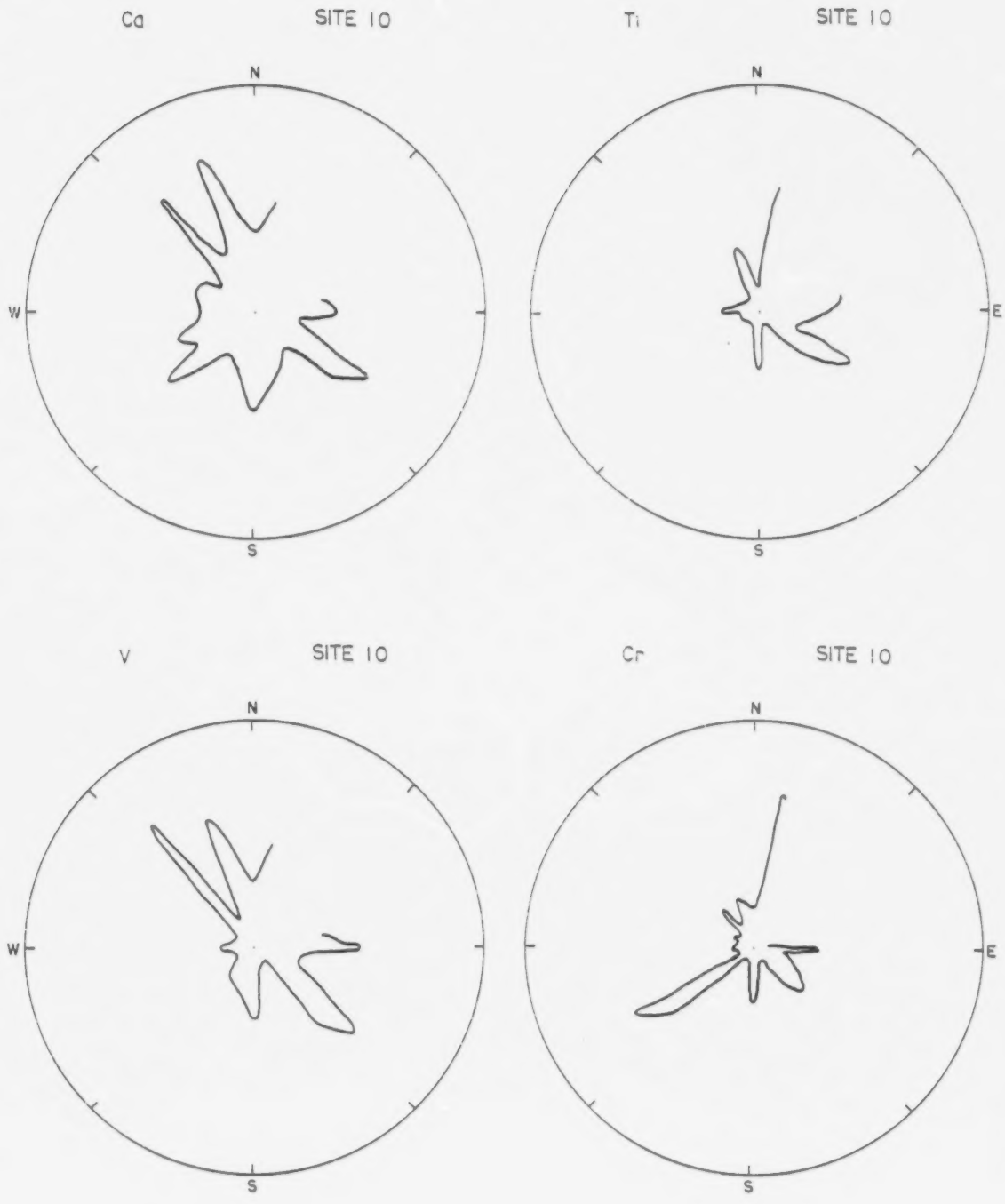


Figure 24. Angular distribution of Ca, Ti, V, and Cr, site 10.

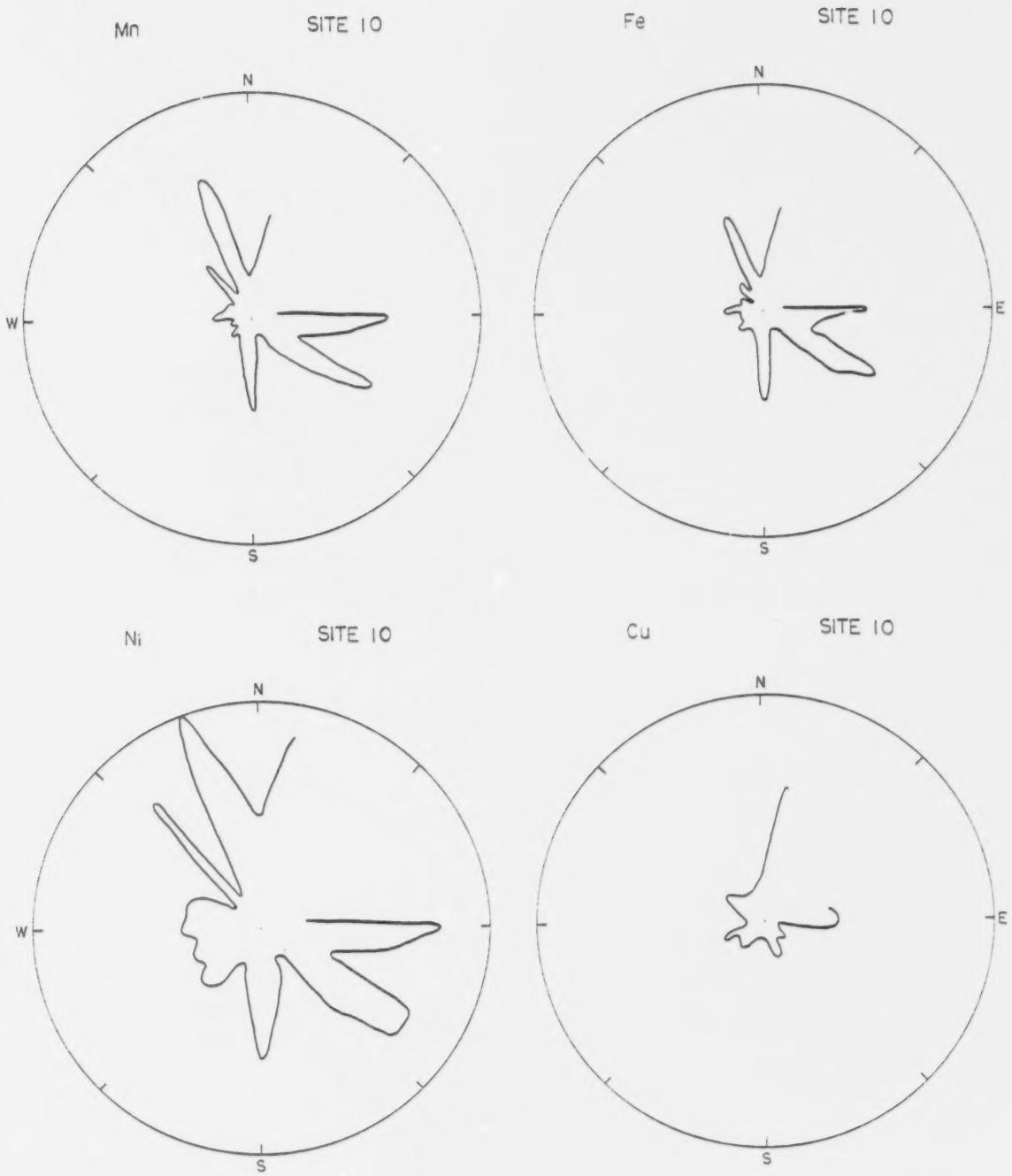


Figure 25. Angular distribution of Mn, Fe, Ni, and Cu, site 10.

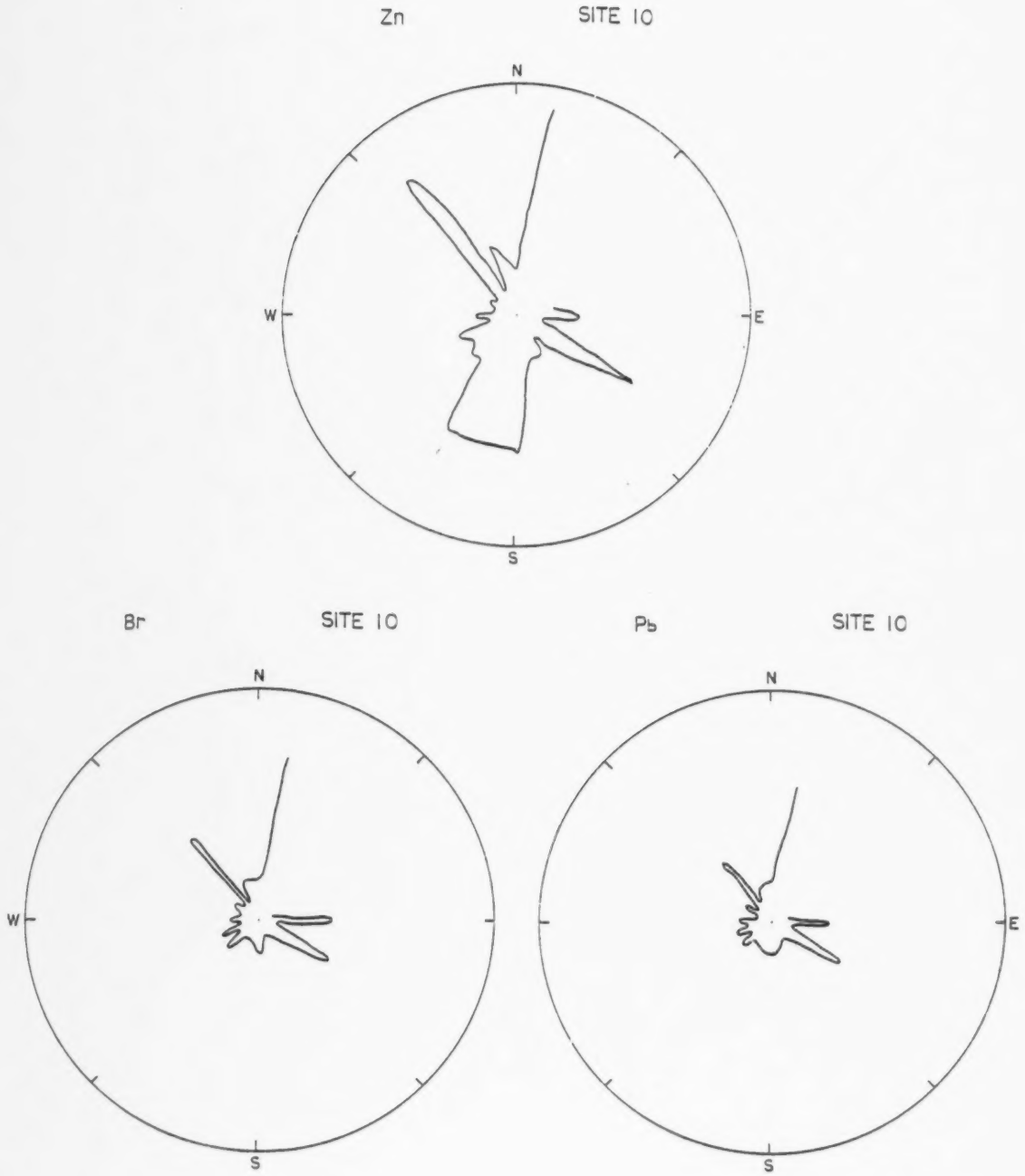


Figure 26. Angular distribution of Zn, Br, and Pb, site 10.

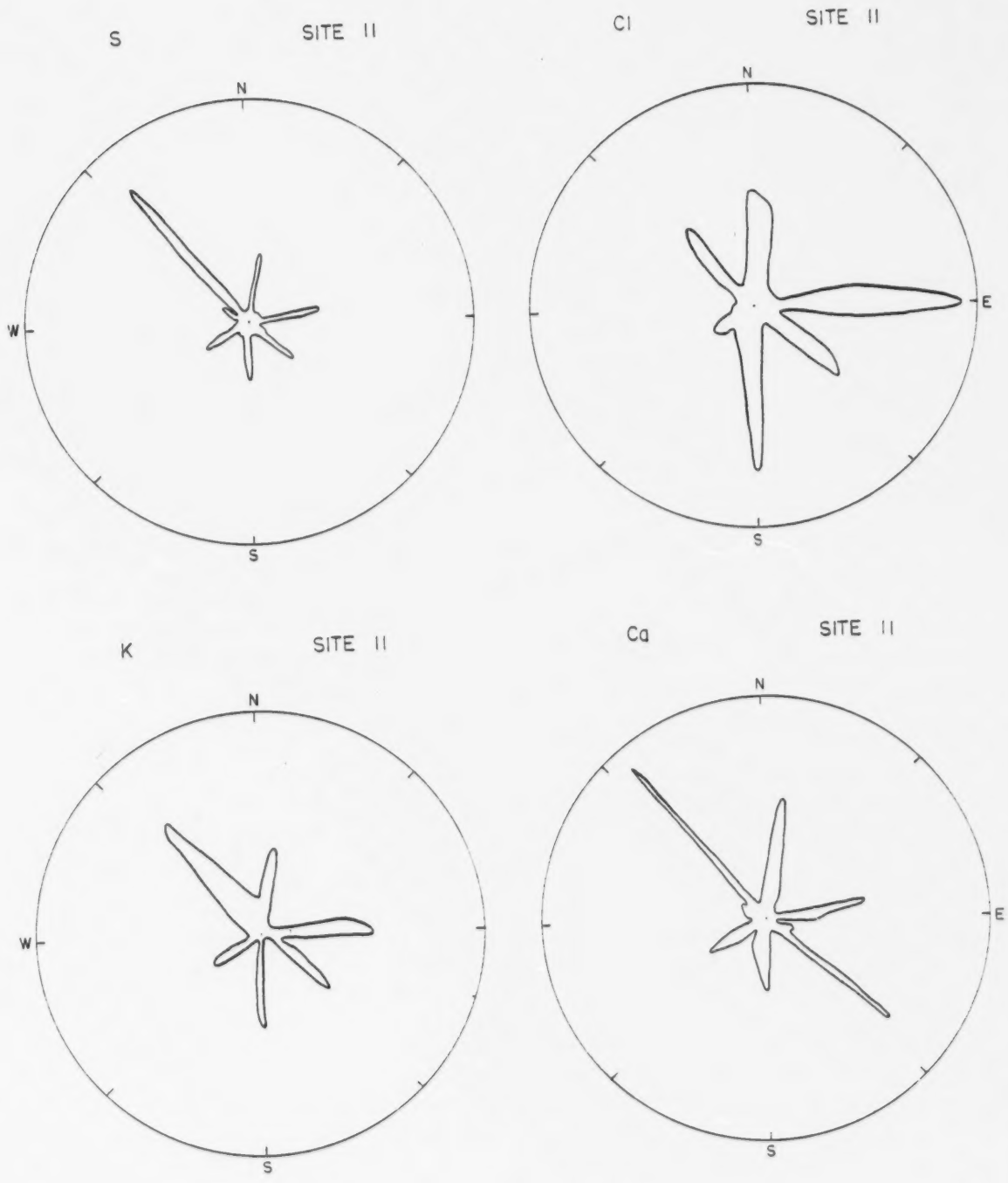


Figure 27. Angular distribution of S, Cl, K, and Ca, site 11.

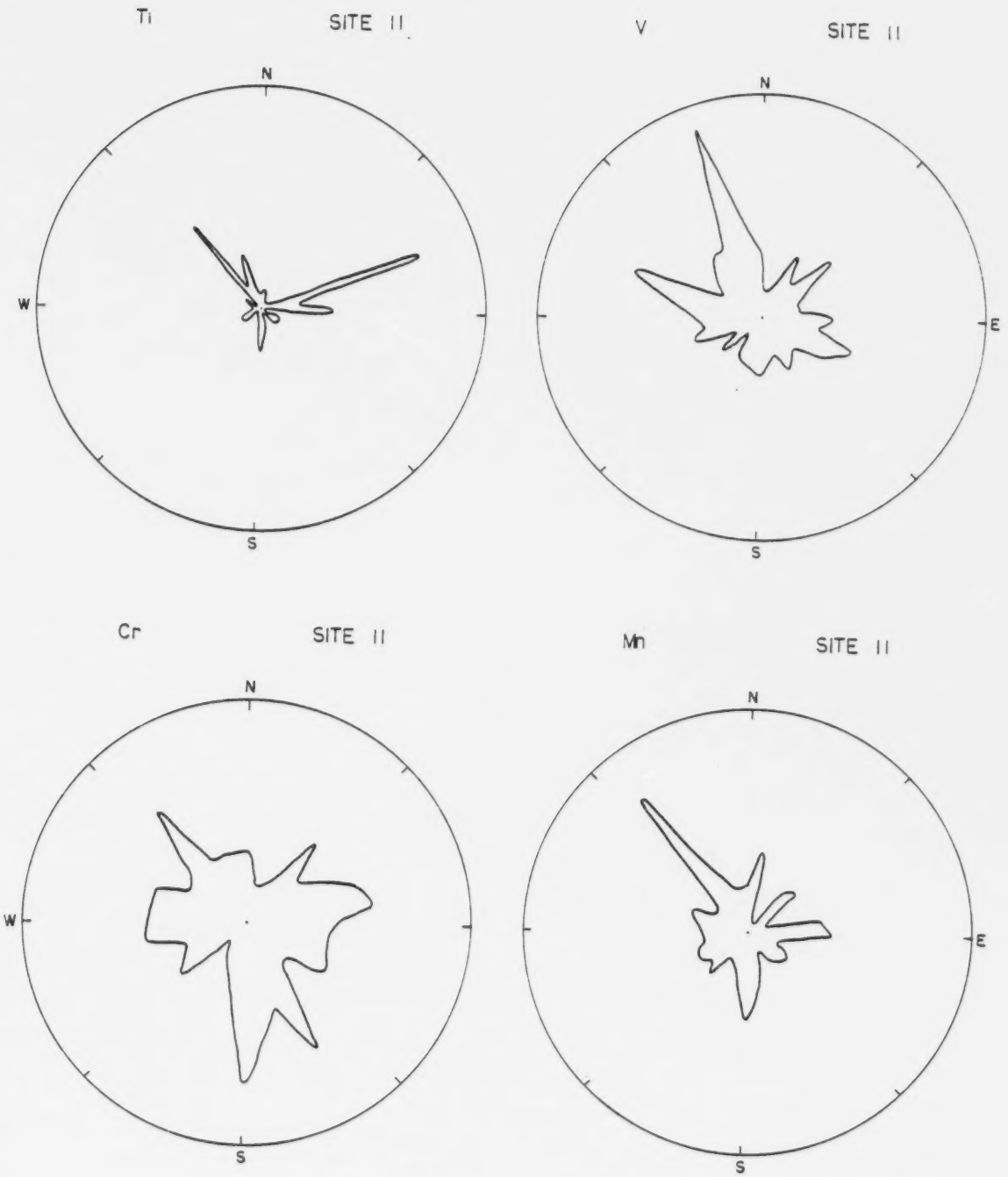


Figure 28. Angular distribution of Ti, V, Cr, and Mn, site 11.

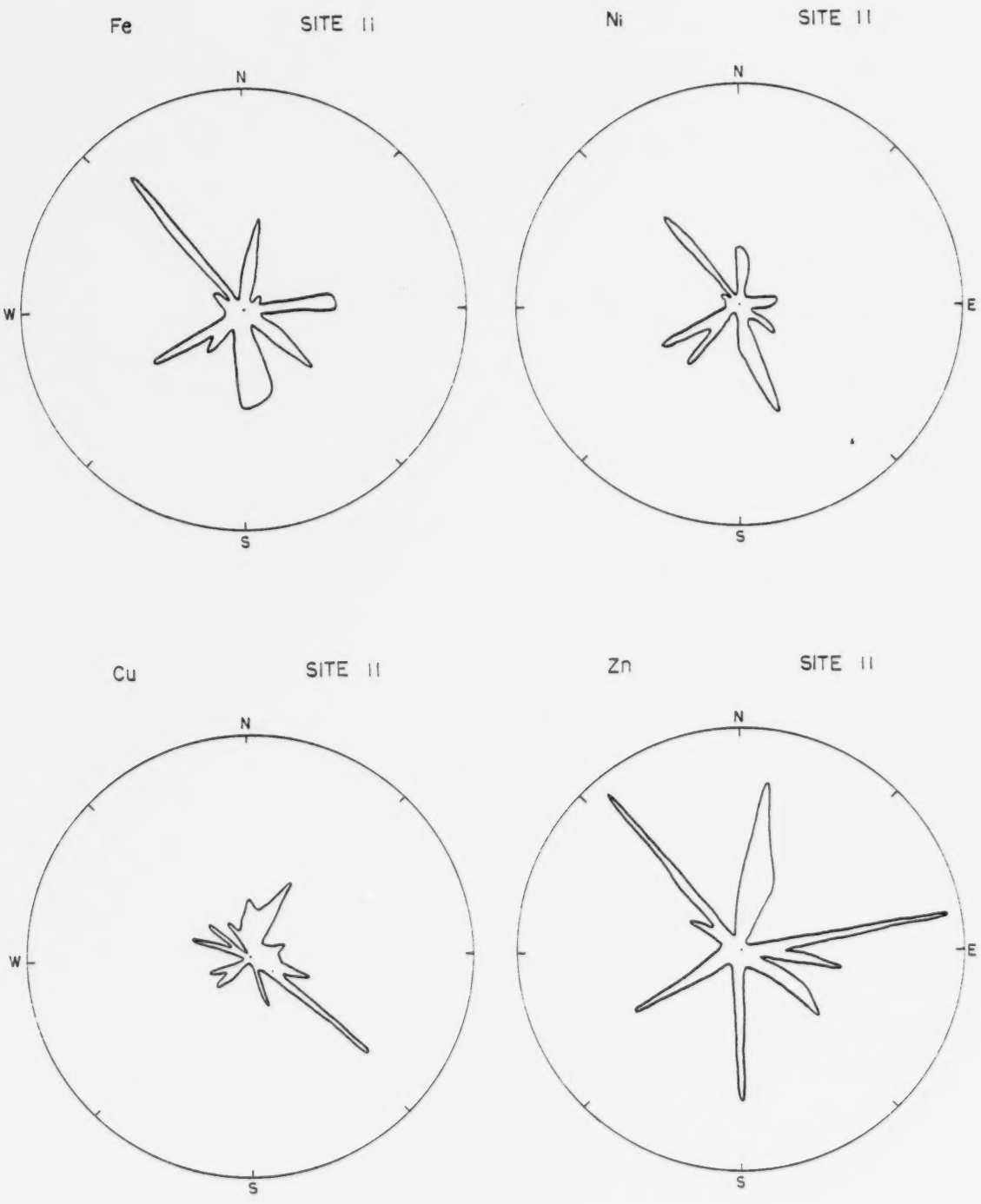


Figure 29. Angular distribution of Fe, Ni, Cu, and Zn, site 11.

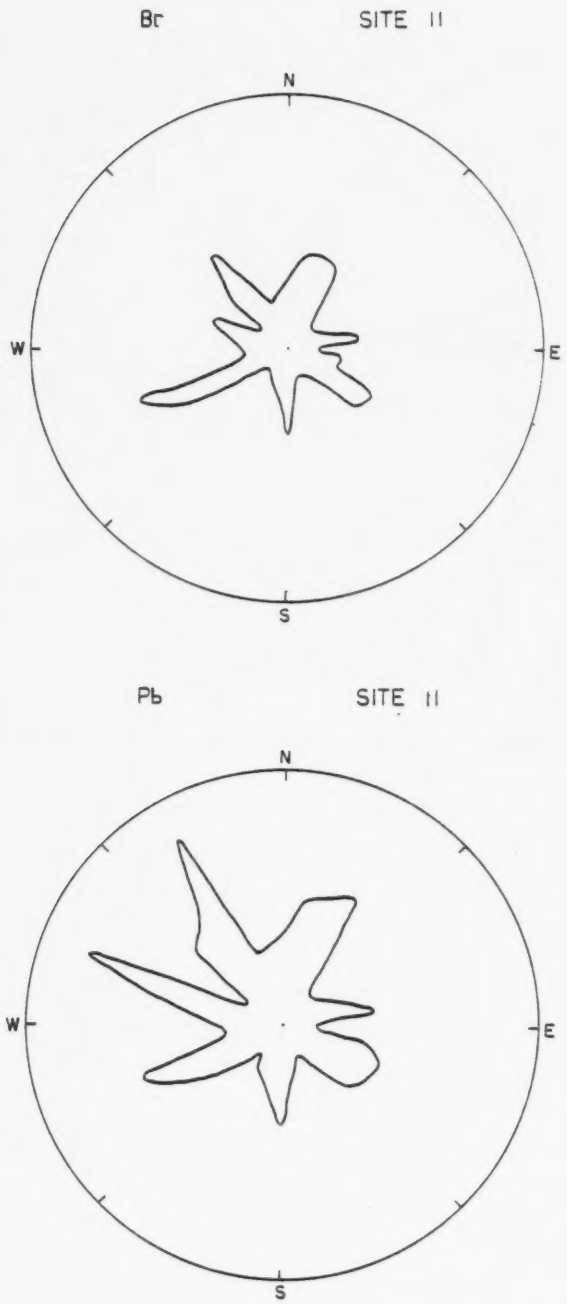


Figure 30. Angular distribution of Br and Pb, site 11.

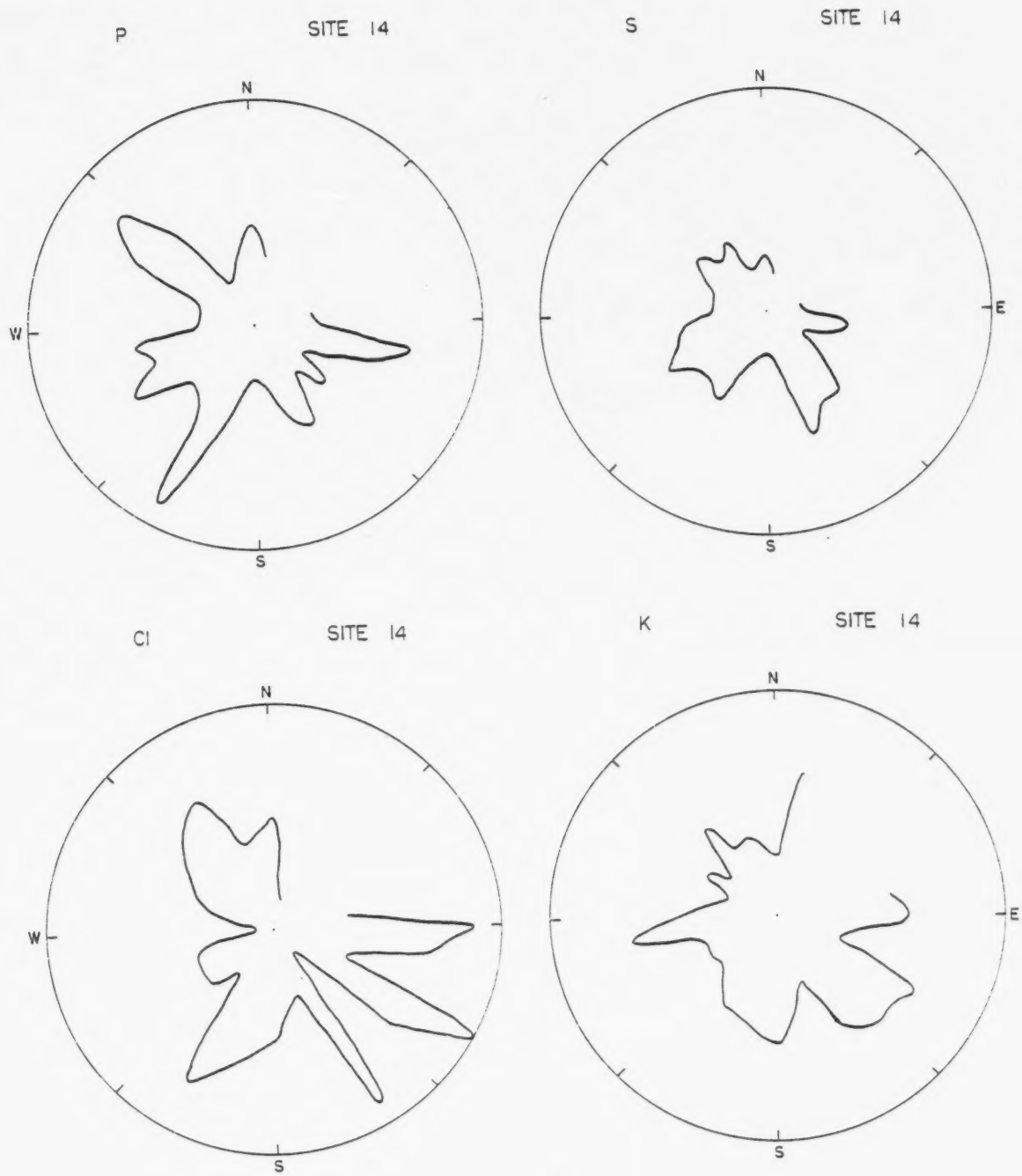


Figure 31. Angular distribution of P, S, Cl, and K, site 14.

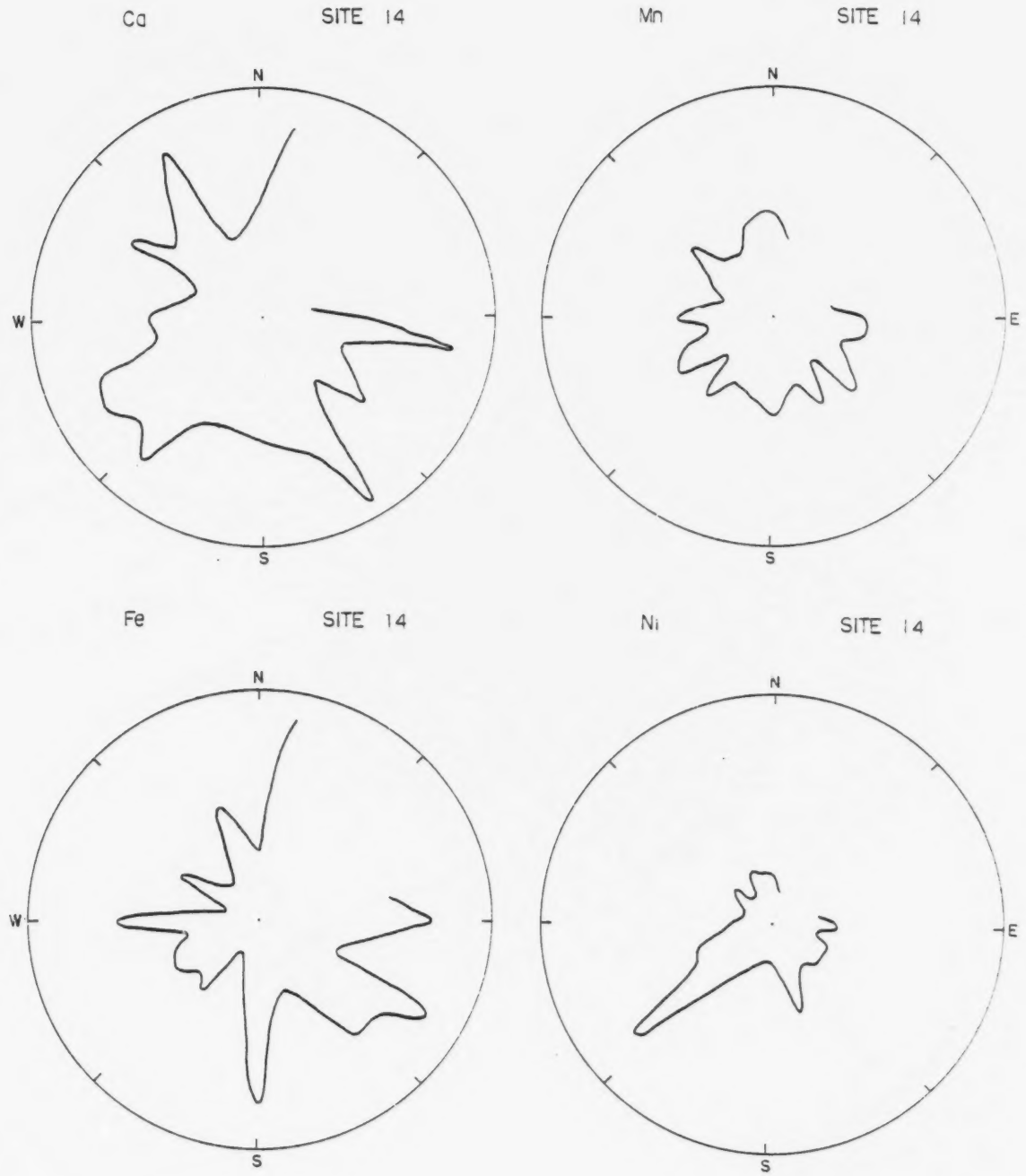


Figure 32. Angular distribution of Ca, Mn, Fe, and Ni, site 14.

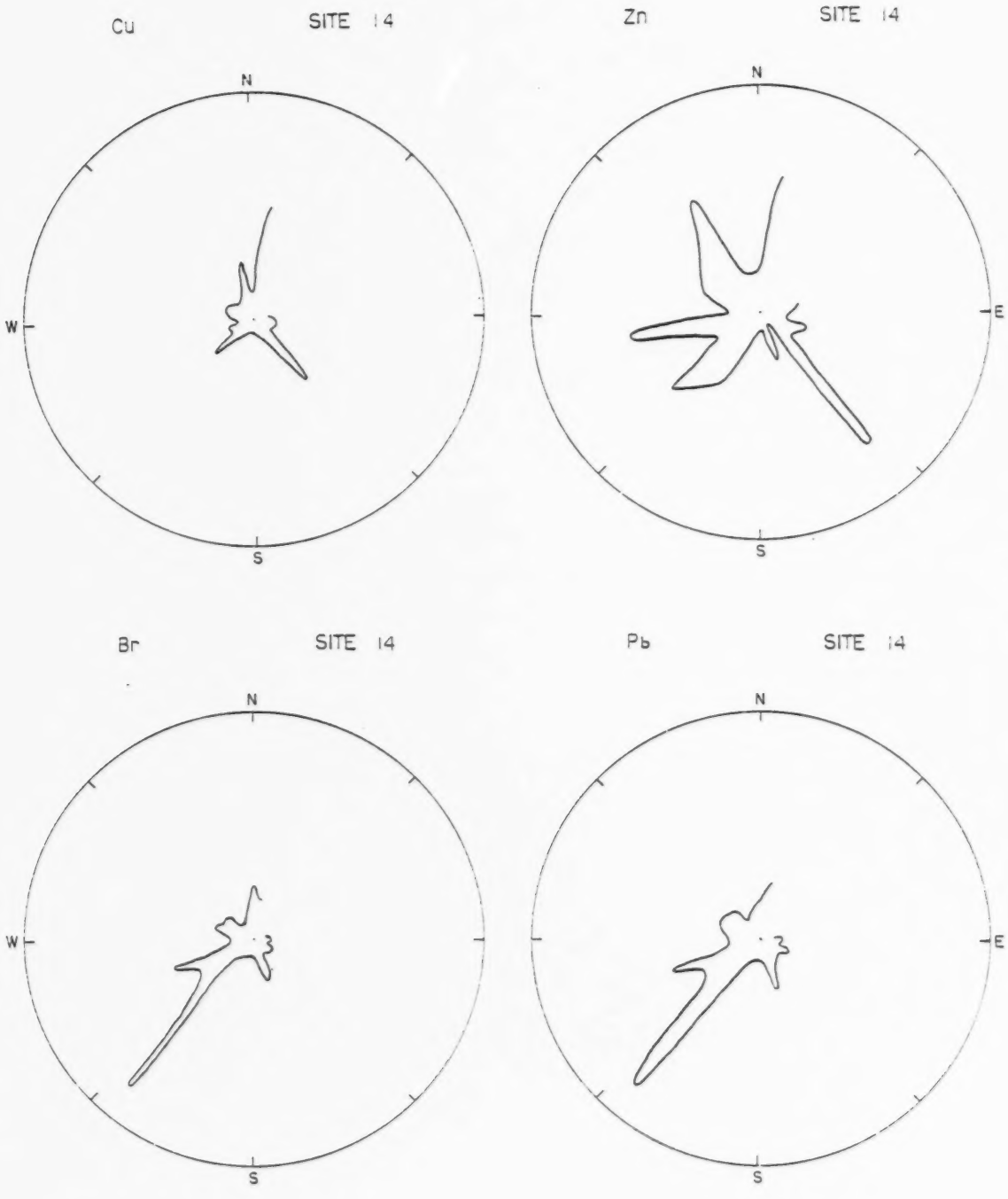
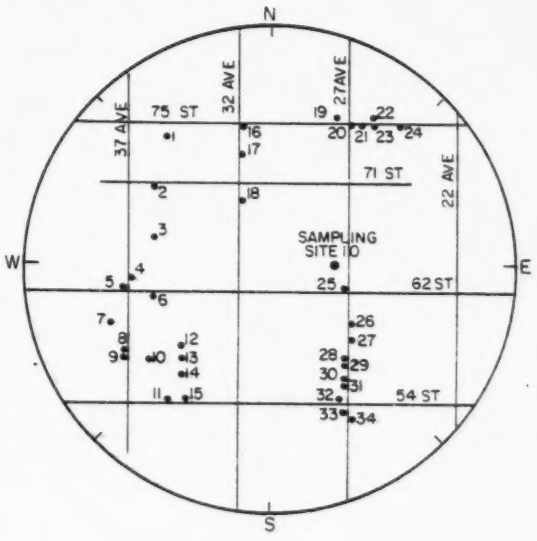


Figure 33. Angular distribution of Cu, Zn, Br, and Pb, site 14.

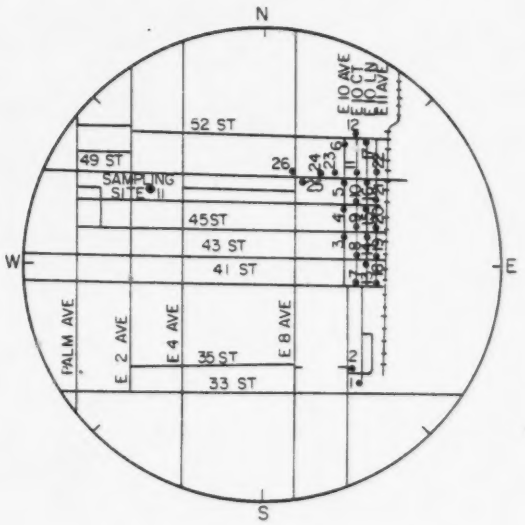


Key:

1. Pioneer Metals
2. Arrow Chemicals
3. Inland Steel Container
4. Wonder-Cote
5. American Tire Corp.
6. American Chemical Company
7. Consolidated Oil
8. Burda Metals
9. Russel Metals
10. Court Paper Company
11. Dixie Plywood
12. American Robin (zippers)
13. Stanley's Truck and Auto
14. Biscayne Paper Co.
15. Seoane General Welding
16. Killiam's Paint & Body
17. Hubbel Metals, Inc.
18. B & B Welding
19. Grand Prix Boat
20. Inter-American Auto Painting
21. Miami Concrete
22. Star Chemical
23. Automotive junk yard
24. Britt Metal Processing
25. Radiator Shop
26. Metro-Dade County Transit Agency
27. Ceasar's Auto Repair
28. Robert's Paint & Body
29. Miami Jack Service
30. J. H. Vamper Body Shop
31. Scotti Body Shop
32. Eliot's Body Shop
33. Norton Tire Co.
34. Banner Tire Co.

Figure 34. Possible particulate sources near sampling site 10.

Figure 35. Aerial photograph of site 10.



Key:

1. Owens Illinois Forest Products Division
2. Pan American Plastics Company
3. Smyth Van and Storage
   Freddie's Auto Repair
   Arnold Gertner & Co.
   Hector Auto Paint
4. A & B Automobile Shop (paint and body)
   A & T Auto Electric Co.
   Beck's Trunk Repair & Service
5. Robert's Cutting Service
   The Schum Co. of Fla., Inc. (metal manufacturing)
   Action Metal Products
   Hialeah Welding Shop
   Hialeah Paint & Body Shop
   Hialeah Auto Electric
   Twin Service Station
6. Mobil Service Station
   Roger Century Paint & Body Shop
   Bayamo Paint & Body Shop (and radiators)
   Rock-Master Inc. (general welding)
   Aires Auto Repair
7. Emil's Radiator Service
   Wesco Inc. of Hialeah (welding)
8. Smyth Van and Storage
   Modelo Auto Paint & Body Shop
9. Luis A. Gonzales Paint & Body
   Solar Auto Repair
   MCD Sales and Auto Repair
   Associated Machine Company
   Wm. Harrison Co. (metal fabrication)
   John Henry Aluminum & Iron Furniture Repair
   Friendly Auto Paint & Body
   Antons Garage
   Tio y Sobrino Paint & Body
   Florida Optical Manufacturing Co.
   Sure-Snap Corp. (snaps, zippers, fasteners)
10. Gregg Tool & Die Co., Inc.
    Summit Products Co.
    Industrial Shop Fork Lift, Inc. (welding and repairs)
    Caballero Paint & Body Shop
    Steel Rule & Die Co.
11. Union 76 Service Station
    G & G Auto Repair
    Allied Plating Supplies
    Sermor, Inc.
    Grundy Neon
    Aircraft Welders
12. Modern Painting Co.
    X-Part Paint & Body (auto repair)
    Used Car Parts & Radiator Service
    Orlando Transmission Service
    Orlando Auto Repair
13. Universal Auto Radiator, Inc.
    Tesco Chemical, Inc.
    Studio of Sculpture, Inc. (mannequin refinishing)
14. Hialeah Welding & Ornamental
    Hialeah Electric Motor Repair
    Screen Art Poster, Inc.
    Hialeah Aluminum Co.
    PVC Fabricators
    Magnum Sheet Metal, Inc.
    Phillips Batteries Co., Inc.
    H & R Tool Specialties, Inc.
15. Pacific Waste Supplies (general welding)
    Eddies Service (autos)
    Viamontes Two Tone Paint & Body
16. Do Campo Trucking Repair, Inc.
    P & D Boat Corp.
17. Auto Car Parts (junk yard)
    Magna Used Auto Parts (junk yard)
    Continental Bumper Plating Service
    J & E Metal Products (welding)
18. Jorges Ornamental Iron
    Deka Batteries Factory Sales
    Hasco Sales, Inc. (garbage container manufacturing)
19-20. Andrew Roofing
    Key Marine
    Pan National Fence Mfg. Co.
21. Royal Precision Products Corp.
    Engler Engineering Corp.
    House Sheet Metal Shop
22. Dade Oil Company (Union 76)
    King Iron Works
    Eastern Steel Corp.
    Used Auto Parts (junk yard)
    Hialeah Radiator & Air Conditioning Service
    Auto junk yard
    J & J Metals (truck repairs and welding)
23. Hess Oil Service Station
24. EXXON Service Station
25. Texaco Service Station
26. Standard Oil Service Station

Figure 36. Possible particulate sources near sampling site 11.

Figure 37. Aerial photograph of site 11.

Key:

1. Metro-Dade Fire Department--Maintenance
2. Alexander Orr, Jr. Water Treatment Plant
3. Alexander Orr, Jr. Water Treatment Plant--Maintenance
4. Standard Oil Service Station
5. Quik Mart Service Station
6. AMACO Service Station
7. Exel Service Station
8. EXXON Service Station

Figure 38. Possible particulate sources near sampling site 14.

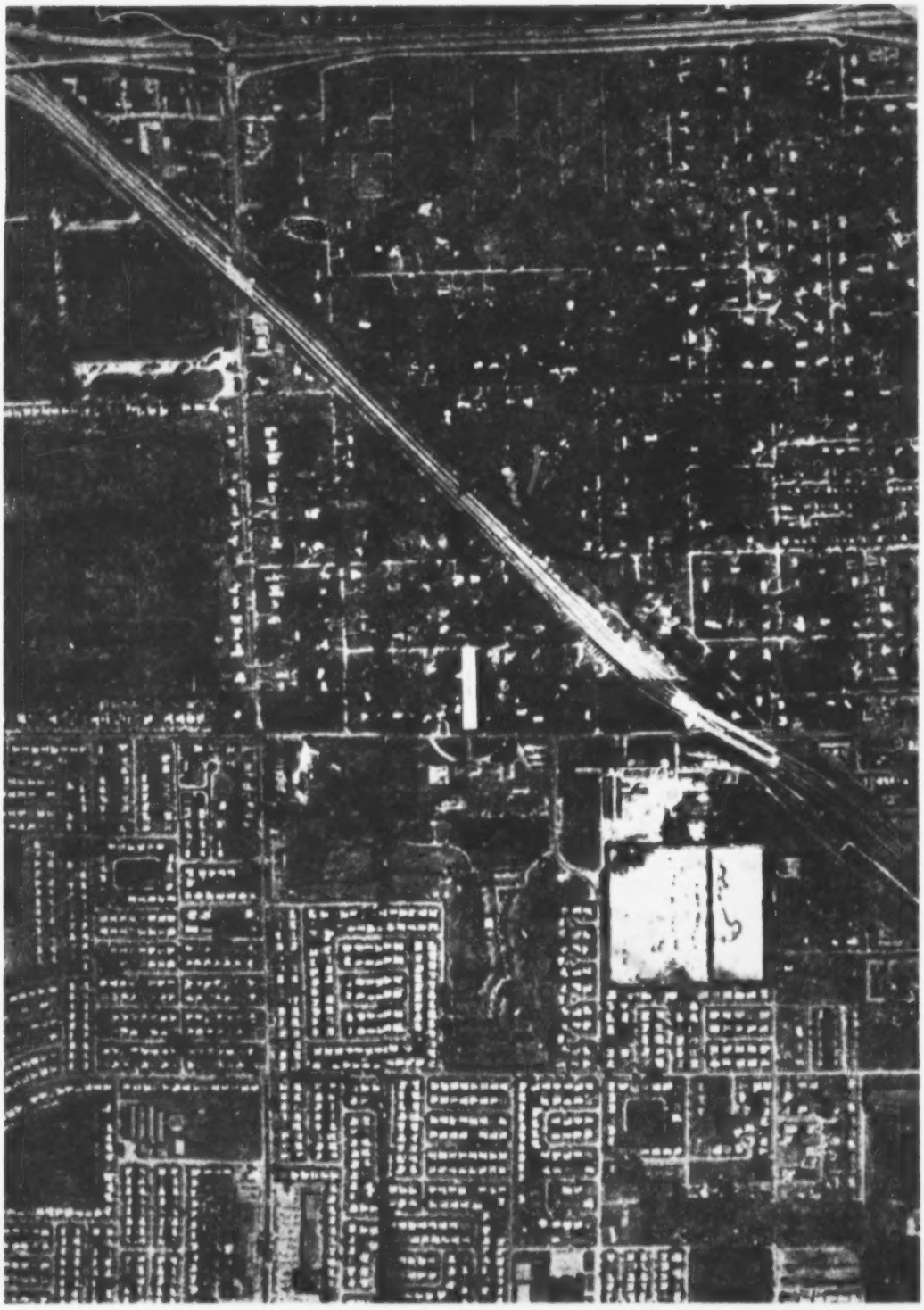


Figure 39. Aerial photograph of site 14.

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